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Characters Connected With the Yield of the Corn Plant

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CHARACTERS CONNECTED WITH THE YIELD OF THE CORN PLANT

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In 1909 the Department of Agronomy of the Missouri Experiment Station began a study of the factors influencing the development of the corn plant. In 1914 this department was divided into the Departments of Soils and Field Crops, which thereafter separately carried on those phases of the study most appropriate for their respective attention. The study as a whole ended in 1920. That part of it directly concerned with the effect of nutrition upon growth has been reported by Duley and Miller.[1] That part concerned with the correlations between structure and function will be reported in this paper.*

I.—A Study of the Correlation Between Yield and Certain Characters of the Corn Plant.

The essential purpose of this study was to contribute to the solution of a problem then (1914) receiving much attention in the field of plant genetics—the correlation between yield and measurable variations in the visible characters of the corn plant. It is a familiar problem to all who have read closely the agronomic literature of the past 12 years. Likewise its conclusion, though never a real solution, is nearly conventional, for almost without exception its investigators have reported (1) that the correlations did not exist or (2) that those observed were not significant. The brief results reported in this paper are not exceptional to the ensemble of evidence from similar studies by other investigators. They are reported because (1) though brief, they contribute a clear case and (2) the great weight of concordant evidence now existing would seem almost to preclude a pos-

[1]This and subsequent numerical references are to the Bibliography.

*The writer had no connection with this project. He is merely a reporter of results secured in 1910, 1911 and 1914, from studies by C. B. Hutchison, C. E. Neff, S. B. Nuckols and others. His presentations and interpretations are therefore critical. Possibly the original investigators would have presented their data more accurately; possibly they would have interpreted it differently.

sibility that further study of the problem by the present conventional methods would prove fruitful.

REVIEW OF RELATED LITERATURE

To review in detail the evidence contributed by previous investigators would show to many readers a familiar picture. It seems unnecessary to do that. Therefore the following brief summary presents only the essential developments.

In 1909, Montgomery[2] reported that a long (large) ear, medium depth of the kernel and stockiness of the stalk, were correlated with relatively high yield. Variation in other characters of the plant and ear showed no relation to yielding ability. The correlation between size of the ear and yield is of course obvious —one is an expression of the other. In the same year Hartley[3] reached this very pointed conclusion—"No visible characters of apparently good seed ears are indicative of high yielding power." He had made more than 1,000 ear-rows tests of 4 varieties, over a period of 6 years.

In 1910, Pearl and Surface[4] said they found no evidence of close association between the conformation of the seed ear and the yield that it produced. They had studied two very different types of sweet corn, giving particular attention to the shape of the ear and the covering of the tip. Ewing[5] after a very thorough study of the variation in several dimensional characters, such as height, and leaf breadth, concluded that "No single character among those studied has shown itself so closely connected with yield as to stand out as a safe guide to the breeder."

In 1911, Love[6] concluded that no characters of the ear were highly correlated with earliness and that none could serve as an index of earliness. Sconce[7] an Illinois seed corn breeder, after a study of 6 years, stated his belief that the number of kernel-rows, the form of the kernel and the size of the germ were correlated with the yield of grain. Funk[8], another Illinois seedsman, while not denying the existence of correlations, concluded that the conventional corn score card does not emphasize the points that affect yield. When he maintained by selection the type which made the highest yields, he gradually produced an ear very different from that idealized by the score card.

In 1913 McCall and Wheeler[9] presented their interpretations of various statistical data of other investigators. They concluded

that significant correlations between yield and length, weight, circumference and density of the ear, had not been shown.

In 1914 Williams and Welton[10] made an exhaustive report of studies through a period of 10 years. As an average, long ears showed an advantage in acre yield of 1.39 bushels over short ears; but tapering ears showed an advantage of 1.65 bushels over cylindrical ears; bare-tipped ears 0.34 bushels over full-tipped ears; smooth-dented kernels 1.76 bushels over rough-dented kernels; and ears of a high shelling percentage (88.16) were 0.52 bushels lower in acre yield than ears with a low shelling percentage (76.07).

In 1916, Cunningham[11] reported that smooth and medium smooth kernels outyielded rough kernels by a considerable margin. Variation in several other characters showed no correlation with yield. He concluded that correlations were variable with the environment.

In 1917, Love and Wentz[6] found that "The characters of length, ratio of butt to tip, average circumference of cob, weight of ear, average weight of kernels, number of rows of kernels, and average length and width of kernels in seed ears do not show correlations significant enough to be of value in judging seed corn." They reached this conclusion after five years of study with one variety. Hughes[12] believed the first year's results of his experiment with seed corn indicated a close correlation between yield and the ear characters idealized by the score card.

In 1918 Hutcheson and Wolfe[13] believed they had found significant correlations between yield and the size and trueness to type of the ears. Many other characters, such as shelling percentage, number of rows, space between rows, and the filling of the butt, were not related to yield in a significant way. Olson, Bull and Hayes[14] from apparently the soundest and most comprehensive study yet conducted, failed to find a significant correlation between yield and any of a broad range of characters observed. They made the very practical statement that "Close selection for high scoring ears is of no practical value in increasing yield."

MATERIAL AND METHODS

Ten ears of each type in the following groups were selected from the variety Boone County White, as seed for the crop in which the correlation study was to be made.

A. Long, slim, smooth ears
B. Long, thick, smooth ears
C. Short, thick, smooth ears
D. Medium long, medium thick, medium rough
E. Long, slim, rough ears
F. Long, thick, rough ears
G. Short, thick, rough ears

Each of the 70 ears was planted in an ear-row, each type in a separate series. Thus there were 10 ear-rows of long, slim, smooth ears; 10 of long, thick, smooth ears; and so on. The series were contiguous and each fifth row was a check, planted with seed of one type. The hills were spaced 44 inches apart, each way, and two plants were left in each hill as the final stand. The crop received ordinary cultivation. Just before the tasseling stage 40 normal plants in each row were labeled, each plant standing among similar normal plants. There were labeled a total of 2800 plants and for each the following data were recorded:

1. Date of tasseling.
2. Date of silking.
3. Number of tillers at full growth.
4. Leaf area above the ear at full growth.
5. Leaf area below the ear at full growth.
6. Total leaf area at full growth.
7. Height of ear at full growth.
8. Relative position of the ear-shank.
9. Height of stalk at full growth.
10. Number of nodes in stalk.
11. Circumference of first internode above ground, at full growth.
12. Circumference of first internode above ear, at full growth.
13. Tassel length.

When two ears were borne by a plant, all measurements with reference to the ear were made by the upper ear only, although the total yield of both ears was determined. The leaf area was the

sum of the areas of individual leaves measured by Montgomery's formula—Area=12x¾ (breadth x length). The tassel length was measured by finding the sum of the length of five average lateral branches, dividing this sum by five and multiplying the quotient by the number of laterals, then adding to the product the length of the central spike. Sound ears were gathered from 1,761 of the 2,800 plants measured, and stored under good drying conditions for six weeks. The weight of shelled grain produced by each plant was computed on the basis of a uniform content of moisture.

THE RESULTS

The mean yields of shelled grain produced by plants from the various types of seed-ears are shown here.

TABLE 1.—THE RELATIVE PRODUCTIVITY OF SEED FROM DIFFERENT TYPES OF EARS.

Series	Type of original seed ear	No. of ears harvested for yield test	Mean yield in ounces of shelled grain per plant	Probable error (±)
A	Long, slim, smooth	195	7.7400	.1409
B	Long, thick, smooth	228	7.7150	.1169
C	Short, thick, smooth	256	8.1836	.1209
D	Medium long, medium thick, medium rough	264	7.9924	.1100
E	Long, slim, rough	256	8.7740	.1182
F	Long, thick, rough	270	8.2741	.1190
G	Short, thick, rough	292	8.2363	.1111
	Composite	1761	8.1525	.0452

The mean yields range highest in Series E, F, and G, and lowest in Series A, B, C, and D. But between the highest yield, Series E, and the lowest, Series B, there is a difference of only 1.06 ounces of shelled grain per plant. This difference, though small, might be significant did not the yields of the check rows (Figure 1) show that Series E was favored by a variation in the fertility of the soil. Doubtless Series F and G were likewise favored.

There were then no significant differences between the yields of plants produced from the various seed-ears representing an extremely wide range of form and identation, in the variety Boone County White.

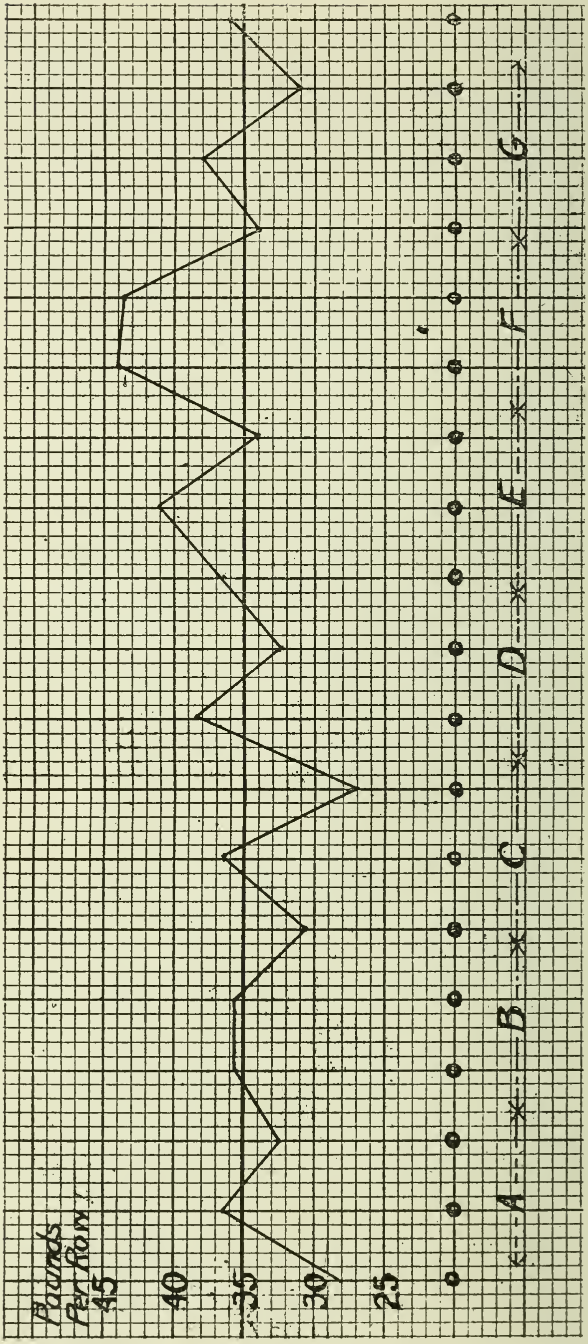

Fig. 1.—Showing the comparative location of Series A to G, and the location and yield in pounds of grain per row of the check rows marked O.

The correlation coefficients determined for the weight of shelled grain as the subject and various plant characters as the relatives are now shown.

Table II.—Correlations Between Variations in Plant Characters and Weight of Shelled Grain per Plant.

Character	Coefficient of correlation	Probable error (±)
Days from planting to silking	-.4181	.0133
Leaf area above ear	.0885	.0167
Leaf area below ear	.0565	.0167
Total leaf area	.0702	.0161
Height of stalk	.1109	.0160
Number of nodes in stalk	.0843	.0161
Height of ear	-.0006	.0161
Relative position of the ear-node	.0340	.0161
Circumference of internode above ground	.1846	.0155
Circumference of internode above ear	.0893	.0160
Length of tassel	-.1251	.0170
Number of tillers	-.0160	.0160

Although some of these correlations are statistically significant, none of them are high enough to be valuable as an index of yield. The negative correlation between yield and the age of the plant at silking, the highest correlation found, would doubtless vary greatly with the season.

DISCUSSION

The results of this brief study are concordant with those of other studies herein cited, in finding no significant correlations between the yield of the corn plant and variations in its visible structures and characters. But these and all similar results make no proof that such correlations do not exist, although the total evidence has come from a very exhaustive analysis. To accept fully the negation of correlations would lead to the conclusion that the corn plant is exhibiting the phenomenon of no relationship between external structure and function. Of course the correlations exist.

Why then are they not found in a measure that would justify

their use as an index of the relative ability of the progeny to yield? A very simple explanation may be suggested.

In all studies of such correlations yield has been treated, consciously or not, as a single character of the plant. Obviously, this conception of yield is fundamentally wrong. Yield is a performance, not a character. It is the ultimate performance of the whole complex relationship of functions and structures that make up the plant. No doubt each function and structure varies with the environment. No doubt each variation influences yield; but only as it contributes to the final complex result of all variations. And so the influence of a given variation upon yield cannot be finally measured, simply because it cannot be identified and separated from the combined influence of innumerable other variations.

But is there no visible index of yielding ability that may serve as a guide in the practical operation of selecting seed corn? It was to answer this question that all correlation studies of corn were begun. Certainly there is such an index. It is yield itself—almost the old and simple idea of selecting the biggest ears.

Taking as an example any common one-eared variety of the Middle West, the yield of grain from plant to plant must vary with the size of the ear, excluding of course the slight variation in shelling percentage and the losses from unsoundness. So far then as yield can be improved by seed selection, the most exhaustive studies have discovered no better method than field selection of the biggest, soundest ears, well matured and unfavored by apparent differences in their local environment—stand, fertility, and so forth. Or if the plant bears more than one ear, of course its total yield, rather than the size of the individual ear, should be considered. In a given environment the best adapted and best yielding strain will of course show some distinguishing characteristic. For example, under certain conditions the highest yielding strain may have smooth kernels. But it does not follow that continued close selection of smooth seed ears will increase or even maintain the yield of the strain. For by that operation a specialized strain not so well balanced with the environment might be produced.

CONCLUSION

Within the conventional limits of a variety of corn, no variation in the visible structures or characters of a normal, healthy plant is a reliable index of the relative ability of its progeny to

yield. The relative yield of the mother plant is the only indication, uncertain as it may be, of the relative yield of the progeny.

This conclusion is based not wholly upon the brief evidence presented in this paper, but upon the total evidence contributed by all investigators of the problem.

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II.—A Study of the Relation of Certain Ear Characters to Shelling Percentage Shrinkage and Viability.

This study was made in 1910 and 1911. Its purpose was to find whether variations in certain characters commonly used in judging seed ears were indicative of the relative shelling percentage, shrinkage and germination.

MATERIAL AND GENERAL METHODS

In 1910, 660 sound ears of a rough, large-eared strain of Boone County White, grown on rich alluvial soil, harvested in December of 1909 and stored in a tightly boarded crib until March 1, were used as experimental material. They will be designated as *Lot A*.

In 1911, 500 sound ears of the same variety, but of a more variable strain, were used. They too had been grown on rich alluvial soil, but had been harvested early in October and air-dried on racks in a mouse-proof seed room for a period of 12 weeks. They will be designated as *Lot B*.

Both lots were selected at random, except with reference to soundness. In both lots the individual ears were described in the details hereafter stated in Tables I—IV. All descriptions were recorded by the same person. No mathematical correlations were determined, but all comparisons were made between two classes showing extreme variation of the character in question, each class constituting about 15 percent of the total number of ears in the lot. For example, in studying the relation of length of ear to shelling percentage in Lot A, the average shelling percentage of the 100 longest ears was compared with that of the 100 shortest ears in the same lot.

THE RELATION OF EAR CHARACTERS TO THE SHELLING PERCENTAGE OF THE EAR

In Table I is shown the relation of various ear characters to shelling percentage, as determined by this method. The differences are in most cases slight and inconsistent. Except the difference between light and heavy ears, which may be attributed to the higher moisture content of the latter (see Table II), the size

and shape of the ear show no significant relation to shelling percentage; but ears marked by deep kernels, narrow kernels, and starchy kernels produced a slightly higher proportion of grain than ears marked by shallow, wide, and horny kernels.

TABLE I.—EAR CHARACTERS AND SHELLING PERCENTAGE.

	Lot A—1910		Lot B—1911	
Character of the ears	Shelling percentage	Ave. weight of grain (grams)	Shelling percentage	Ave. weight of grain (grams)
Long	84.1	451.4	84.4	393.3
Short	86.1	367.5	84.5	347.1
Large circumference	84.4	450.7	84.7	408.3
Small circumference	84.8	371.1	86.3	357.0
Heavy	83.8	464.0	86.0	422.0
Light	89.9	358.5	85.7	327.2
Many rows of kernels	85.0	441.2	85.5	411.6
Few rows of kernels	83.3	384.4	84.5	369.4
Cylindrical	84.1	412.4	85.2	326.5
Tapering	84.4	411.8	84.6	381.0
Rough indentation	84.1	421.7	83.9	396.8
Smooth indentation	84.2	411.8	84.2	337.6
Deep kernels	85.7	450.1	86.4	409.2
Shallow kernels	83.1	383.2	83.2	334.7
Wide kernels	83.8	415.8	84.1	382.2
Narrow kernels	85.2	419.0	85.7	393.0
Horny kernels	82.0	391.2	83.8	346.3
Starchy kernels	85.5	415.8	85.6	379.8

THE RELATION OF EAR CHARACTERS TO THE SHRINKAGE OF THE EAR

The relation of ear characters to shrinkage was studied in Lot B by comparing the length, circumference, and weight of the ears as first stored, with their length, circumference and weight at the close of the total drying period of 6 weeks. The results of this study are shown in Table II.

Little relation is shown between shrinkage and indentation or between shrinkage and the length and shape of the ear. Apparently, however, heavy ears, thick ears, deep-kerneled ears, and ears with a large number of rows, lost considerably more weight than ears of the opposite types.

TABLE II.—EAR CHARACTERS AND THE AVERAGE SHRINKAGE IN LENGTH, CIRCUMFERENCE AND WEIGHT OF EARS OF LOT B.

Character of the ears	Loss in Length		Loss in Circumference		Loss in Weight	
	Inches	Percent	Inches	Percent	Grams	Percent
Long	.4572	4.4	.3825	5.3	69.4	15.6
Short	.3520	4.0	.3843	5.2	61.6	16.5
Large circumference	.4250	4.6	.4624	5.9	75.4	17.0
Small circumference	.3354	3.4	.3329	4.9	49.9	12.6
Many rows	.3790	4.0	.3930	5.1	77.3	17.1
Few rows	.3612	3.7	.2295	3.4	59.8	14.5
Heavy	.5140	5.2	.4183	5.6	92.4	19.1
Light	.3412	3.3	.3300	4.7	44.5	12.8
Cylindrical	.4362	4.5	.4000	5.8	63.9	17.3
Tapering	.3710	3.9	.4000	5.5	65.8	15.6
Rough indentation	.3651	3.8	.3475	4.6	58.2	13.7
Smooth indentation	.4222	4.5	.4030	5.9	67.8	14.2
Deep kernels	.3849	4.0	.3520	4.6	89.7	18.3
Shallow kernels	.3108	3.2	.3700	5.5	59.8	15.7

In the same lot of ears the rapidity of shrinkage was determined by weighing at intervals of two weeks, 300 ears grouped in extreme classes as previously described.

The results are shown in Table III.

TABLE III.—EAR CHARACTERS AND THE PROGRESSIVE RATE OF SHRINKAGE.

Character of the ears	Percentage of Loss in weight						
	2-wks	4-wks	6-wks	8-wks	10-wks	12-wks	Total
Large circumerence	8.6	5.6	1.7	1.1	0.7	0.5	18.2
Small circumference	6.6	5.3	1.6	1.2	0.4	0.4	15.5
Heavy	9.6	6.2	1.6	1.1	0.5	0.5	19.5
Light	6.9	4.5	1.8	0.8	0.3	0.6	14.9
Many rows	8.6	6.2	1.5	1.0	0.6	0.3	18.2
Few rows	7.8	5.2	1.9	1.0	0.8	0.4	17.1
Rough indentation	7.8	5.5	1.7	0.9	0.4	0.5	16.8
Smooth indentation	8.2	5.9	1.8	0.9	0.8	0.6	18.2
Deep kernels	10.5	5.9	1.9	0.9	0.6	0.2	20.0
Shallow kernels	7.9	5.3	1.5	1.2	0.5	0.2	16.6
Horny kernels	8.4	5.7	1.6	1.1	0.2	0.4	17.4
Starchy kernels	8.9	5.7	1.8	1.0	0.4	0.5	18.3

It may be noted first that in all classes of ears more than 75 percent of the total shrinkage occurred during the first four weeks, and that thereafter the shrinkage in all classes of ears was very slight from one two-week interval to another. Weather conditions were about the average for October, November and December in this section. These results then may indicate the probable time required to air-dry seed corn under good conditions of farm storage. Apparently it would not be necessary to keep the seed ears on racks or various other drying devices for longer than a month. They could then be stored in a more convenient bulk without damage because of the moisture they contained. Their remaining moisture would be given off very slowly and uniformly over a long period.

There seems little significance in the relative rates of shinkage by ears of the different types. Large ears and heavy ears lost moisture more rapidly during the first two weeks than ears of the opposite types, due probably to their large, heavy cobs. The comparatively rapid drying of deep-kerneled ears may indicate the desirability of this type for seed, provided they are also large, sound, and well matured.

THE RELATIONS OF EAR CHARACTERS TO VIABILITY

At the time of this study the ears (Lot A) were two years old. They had been harvested in December 1909 and stored for nearly 3 months under rather poor conditions before they were sent to the Experiment Station. Their shelling percentage had been determined (Table I) and the grain of individual ears, stored separately in bottles, had been fumigated several times with hydrocyanic acid gas. In November, 1911 this seed was tested for germination.

To make the tests, kernels were planted at a depth of 1 inch in sand which was kept at a temperature of about 80°F during the day and about 60°F during the night, and in a fairly uniform condition of moisture. A composite hundred kernels from each ear of the 660-ear lot—a total of 66,000 kernels—were planted in two equal series, one 12 days later than the other. Ten days after planting, the numbers of strong sprouts, weak sprouts, and sprouts not appearing above the ground, were counted. The results are given in the following table.

TABLE IV.—EAR CHARACTERS AND GERMINATION.

(Percentage of Germination in 10 Days)

Character of the ears	Strong plants	Weak plants	Plants not above ground	Total germination
Long	34.8	12.1	7.2	54.1
Short	37.3	13.3	9.6	60.1
Large circumference	30.5	11.0	7.3	48.8
Small circumference	45.4	12.9	6.8	65.1
Heavy	28.3	11.8	7.1	47.2
Light	42.2	12.6	7.0	61.8
Many rows (22 and more)	30.9	11.5	6.4	48.8
Few rows (16 and less)	44.7	13.2	7.0	64.9
Twisted rows	39.6	12.6	6.8	59.0
Straight rows	38.1	12.0	6.6	56.7
Cylindrical	38.2	11.8	6.2	56.2
Tapering	39.0	12.4	7.2	58.6
Close spaced rows	42.4	13.7	7.5	63.6
Open spaced rows	37.2	11.6	8.3	57.1
Rough indentation	35.3	12.6	7.5	55.4
Smooth indentation	46.4	11.8	5.4	63.6
Wide kernels	33.4	12.5	7.8	53.7
Narrow kernels	35.5	12.1	5.8	53.4
Deep kernels	27.0	11.4	6.7	46.6
Shallow kernels	44.2	12.9	5.5	62.0
Horny kernels	54.4	8.0	4.4	66.8
Medium horny kernels	39.4	11.8	6.1	57.3
Starchy kernels	36.0	10.1	7.2	53.3
Large germs	34.1	10.9	6.4	51.4
Small germs	41.6	12.4	6.1	60.1
High shelling percentage	30.2	11.5	6.5	48.2
Low shelling percentage	43.6	11.3	5.8	60.7
Heavy grains	32.3	12.6	7.4	52.3
Light grains	37.1	11.9	5.5	54.5
Heavy cobs	33.4	12.2	7.0	52.5
Light cobs	39.3	12.5	6.3	58.1

A brief inspection of the data will show that seed from short ears, light ears, ears with few rows, and ears of small circumference, germinated better than seed from ears of the opposite extreme types. However, it can hardly be assumed that these various characteristics of size bear a direct relation to the viability of the seed. Each of them is in some degree merely an expression of the circumference or weight of the cob; and one might expect a comparatively low germination in seed borne on a large, sappy

cob, because of the unfavorable effect of a higher moisture content. Some verification of this is found in the fact that seed from light cobs germinated 58 percent, while seed from heavy cobs germinated 52 percent.

The data do not show a material difference in the germination of seed from ears extremely variable in shape and in the form and spacing of the kernel rows. However, smooth, shallow, horny kernels, germinated better than rough, deep, and starchy kernels, respectively. Small germs sprouted better than large germs.

It is possible that the treatment of the seed previous to the germination tests—late harvesting, 3 months storage in a crib, and several fumigations with hydrocyanic acid gas—may have affected differently the viability of the various types. Certainly the viability of all types was very low as a result of this treatment.

SUMMARY

1. Ears extremely characterized by deep kernels, narrow kernels or starchy kernels, had a slightly higher shelling percentage than ears of the opposite extremes. No other characteristics of the ear showed a significant relation to the proportion of grain.

2. Heavy ears, thick ears, deep-kerneled ears, and ears with a large number of rows, lost considerably more weight than ears of the opposite extremes, during a total drying period of 6 weeks. These characteristics are of course closely related to the size of the cob. Other characteristics of the ear showed no relation to the total loss of moisture.

3. In all types of ears more than 75 percent of the total shrinkage occurred during the first 4 weeks of a drying period of 12 weeks. Additional shrinkage was very slow over the following 8 weeks period. This indicates that when seed corn has been air-dried on racks or other devices for about a month, under climatic conditions similar to those of this experiment, it may safely be stored in a more convenient bulk.

4. Smooth kernels, shallow kernels, horny kernels, and kernels with small germs, showed a higher viability than kernels of the opposite extremes. No characteristic of the ear as a whole showed a relation to viability which may not be traced to the moisure content of the cob. Possibly the previous treatment of the seed influenced the relative viability of the different types.

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Localization of the Factors Determining Fruit Bud Formation

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LOCALIZATION OF THE FACTORS DETERMINING FRUIT BUD FORMATION

H. D. Hooker, Jr. and F. C. Bradford

Belief in a relationship between slow growth and a fruitful condition in apple and pear trees has come down to the present with the approval of many generations of growers. Said John Lawrence[1], in 1717, concerning the pear: "*****but yet for the sake of that noble Fruit which some Kinds produce by the Help of a Wall, it is worth while to humble him and keep him in Order. For which purpose****I sometimes plash the most vigorous Branches, cutting them near the place from whence they shoot, more than half through, which effectually checks its Vigour, and consequently renders it more disposed to make weaker Shoots, and form bearing Buds."

The chief concern of the older writers on fruit bud formation seems to have been the prevention of excessive growth. This was natural, since they were dealing chiefly with fruit gardens, manured and cultivated and consequently with trees growing luxuriantly. When fruit growing spread to the orchard the literary heritage from the garden survived and though there was an undoubted realization of the unfruitfulness of greatly weakened trees it is but recently that there has been a crystallization into definite phrases of this feeling that a certain amount of growth is necessary for fruit bud formation and that, within limits, fruitfulness and vegetative development are associated phenomena.

SOME OF THE FACTORS INVOLVED

The work of Klebs[2], of Fisher[3], of Kraus and Kraybill[4], and of Hooker[5] has given some conception of the internal chemical factors connected with the initiation of fruit bud differentiation. Briefly stated, this seems to be associated primarily with carbohydrate accumulation and in apple spurs, with starch storage in particular. However, even though carbohydrate accumulation occur, fruit and differentiation does not take place if there be a limiting factor which seriously retards or altogether stops vegetative growth. The inference seems warranted, therefore, that the supply of water, of heat[6], of nitrates or of any other essential nutrient

may so check growth and carbohydrate utilization that carbohydrate accumulation results, if conditions be favorable for carbohydrate manufacture; any one of these factors may become limiting and prevent fruitfulness, though under field conditions the nitrogen supply seems to be the factor most frequently operative in this direction. When the nitrogen supply is plentiful, carbohydrate is usually found in the plant in small amounts, because it has been utilized in growth; when the nitrogen supply is low, carbohydrate is usually found accumulated in relatively large amounts. In the two year cycle involving fruit bud differentiation one year and fruit formation the next, through which most apple spurs on fruitful trees usually pass, starch accumulation is associated with a relatively low nitrogen content during the period of fruit bud differentiation the one year and a practical absence of starch is associated with an exceptionally high nitrogen content during the period of fruit setting the other year.

It should be pointed out that this inverse correlation between nitrogen and carbohydrate (particularly starch) content does not represent a relationship of fundamental importance for fruit bud differentiation. It is, in a sense, accidental, though it is common because nitrogen supply is most often the limiting factor determining carbohydrate accumulation. In case some other factor, for example water supply, were operative in checking growth, it is clear that carbohydrate accumulation might take place even in the presence of abundant nitrogen. In fact some such situation must obtain in those spurs on certain apple varieties which form fruit buds regularly every year. If fruit setting depend on the presence of a relatively large amount of nitrogen in the spur as Harvey and Murneek[7] suggest and if fruit bud differentiation depend on starch accumulation, then large amounts of nitrogen and of carbohydrates must be present almost simultaneously in these spurs. This situation has been observed in spurs of Payne's Late Keeper, a local variety in which a large percentage of the spurs are characterized by successive fruit bud formation. A sample of bearing spurs collected July 3, 1920, had 1.236 per cent nitrogen and 3.16 per cent starch. Comparison of these figures with the data published in Research Bulletin 40 of this Station shows that this nitrogen content is of the order found in spurs of other varieties during the spring of their bearing year and that the starch content is equal in amount to that found in those spurs of these varieties that are differentiating fruit buds.

THE RELATION OF GROWTH TO PERFORMANCE

The fact that very little growth and very vigorous vegetative development are alike unfavorable for fruit bud differentiation suggests relationship between spur growth and spur performance in the apple. Roberts[8] found that in Wealthy and other apple varieties under certain conditions spurs of certain length growths showed the highest percentage of fruit bud differentiation and that both longer and shorter spurs showed lower percentages.

To establish, for closer selection of samples for chemical study, the value of such an index to the probable performance of the individual spurs under conditions obtaining in the trees growing in the University orchard at Columbia studies of spurs of several varieties were undertaken. Measurements totaling around 13,000 were made, work proceeding with each variety till several successive series showed no change in the results obtained. For purposes of this investigation no spur was considered which had not blossomed at least once; growth in one year of over 10 cm. was arbitrarily considered to remove the twig from the spur class to the shoot class. The massed results are shown in Table 1, in terms of percentage of spurs in each class forming fruit buds. The figures presented here are from purely vegetative growths, i. e., no measurements of growth of any spur in its blossoming season are in-

TABLE 1.—PERCENTAGE OF SPURS OF VARIOUS LENGTH CLASSES WHICH FORMED FRUIT BUDS

Length (cm.)	Gano	Jonathan	Devonshire Duke	Wealthy
0.1-0.5	17.5	39.3	15.3	49.7
0.6-1.0	45.7	53.8	17.5	62.9
1.1-1.5	60.6	57.0	11.9	62.5
1.6-2.0	69.2	76.8	30.0	76.3
2.1-3.0	65.3	60.4	25.0	62.8
3.1-4.0	74.6	72.7	---	64.8
4.1-5.0	70.7	63.3	---	70.0
5.1-6.0	79.2	78.1	50.0	61.1
6.1-7.0	88.6	70.0	---	81.2
7.1-8.0	88.7	100.0	---	66.7
8.1-9.0	80.5	81.3	---	66.7
9.1-10.0	74.0	68.4	---	75.0
3.0-10.0	77.3	75.2	15.5	69.5
Average	54.4	53.4	16.4	60.2

cluded. It may be stated, however, that inclusion of the growths during a season of fruiting made no material difference except in the percentage of fruit buds formed; the relative positions of the various classes remained the same.

These figures show, in each variety, an increase in the percentage of fruit buds formed, with an increase in the growth of the current year. In some, however, the rise from the lowest class to the next higher is much more abrupt than in others, in Gano from 17.5 to 45.7 as compared with a rise from 39.3 to 53.8 per cent in Jonathan. Viewing it in another way: in the lowest growth class Gano formed less than half the percentage of fruit buds that Jonathan spurs making the same growth formed. This difference could not be due to the Jonathan growths averaging nearer the upper limit of the class than did the Gano, for actually conditions were reversed. It seems quite evident that Jonathan will form a greater percentage of fruit buds on very short growths than will Gano.

Were spurs defined as growths up to 3 cm. only, there would be, in all four varieties, a maximum percentage of fruit bud formation in those growths between 1.6 and 2.0 cm. However, in each case, except Devonshire Duke, the percentage of fruit buds formed on growths between 3.1 and 10.0 cm. is higher than in any of the smaller classes. In other words, there is a strong tendency, in the trees examined, for a continuing increase in percentage of fruit bud formation with increase in growth.

Table 2 shows the percentage distribution of these same spurs

TABLE 2.—PERCENTAGE OF TOTAL NUMBER OF SPUR GROWTHS IN EACH LENGTH CLASS.

Length (cm.)	Gano	Jonathan	Devonshire Duke	Wealthy
0.1-0.5	6.7	24.2	40.6	25.1
0.6-1.0	17.4	33.2	45.5	32.3
1.1-1.5	14.0	13.4	7.0	13.8
1.6-2.0	9.3	7.6	5.6	7.4
2.1-3.0	11.7	5.9	0.7	9.5
3.1-4.0	9.7	4.0	0.0	3.3
4.1-5.0	8.2	1.9	0.0	2.3
5.1-6.0	5.7	3.2	0.7	1.6
6.1-7.0	6.7	2.1	0.0	1.8
7.1-8.0	4.5	1.7	0.0	1.6
8.1-9.0	2.7	1.3	0.0	0.8
9.1-10	3.5	1.3	0.0	1.1

in the various length classes. In each variety there is a larger percentage of spurs in the 0.6-1.0 cm. class than in any other. The close parallel in the distribution of Jonathan and of Wealthy spurs is striking. Gano and Devonshire Duke have different curves of distribution.

ANALYSIS OF DATA

Correlation between spur growth and performance implies a considerable degree of autonomy in the spur. If this *quasi* independence be great, then studies of the factors affecting fruit bud formation may well be focused on the spur, taking little heed of the remainder of the tree. Because of the bearing of this matter on other investigations under way the data accumulated from measurements were subjected to closer analysis.

By Years.—Table 3 shows the percentages of fruit bud formation in different years in spurs selected at random from six Gano trees in the University orchard at Columbia, bearing regularly in the odd years. Since these measurements were taken in the winter of 1919-1920 no figures from subsequent years for these spurs are available. Performances in the bearing year of any spur were not considered; consequently all these figures apply to spurs having full opportunity, so far as they were concerned individually, to form fruit buds. This they did abundantly in some years—the off years—and very meagerly in others—the bearing years.

The marked difference between the distribution of spur per-

Table 3.—Percentages of Fruit Bud Formation in Spurs of Different Lengths, in Gano.

Spur length (cm.)	1915	1916	1917	1918
0.1-0.5	57	3	38	1
0.6-1.0	81	4	53	10
1.1-1.5	87	17	59	28
1.6-2.0	94	0	72	0
2.1-3.0	93	20	58	37
3.1-4.0	95	0	71	100
4.1-5.0	94	50	73	0
5.1-6.0	100	50	70	0
6.1-7.0	95	--	80	--
7.1-8.0	100	--	81	--
8.1-9.0	100	0	83	0
9.1-10.0	88	0	87	--

formance in the bearing years of Gano (1915 and 1917) and in the off years (1916 and 1918), as shown in Table 3, indicates that the condition of the whole tree influences spur performance in no small measure. The figures recorded in Table 1 for Devonshire Duke show much the same type of distribution of fruit bud differentiation as is shown by the off years for Gano and the low average percentage of fruit bud formation in the Devonshire Duke suggests an association between the condition of the tree and the character of the distribution curve.

By Trees.—Interesting comparisons between spur performances on two Wealthy trees, standing side by side, are shown in Table 4. One bears biennially in a pronounced manner; the other

Table 4.—Percentage of Fruit Buds Formed by Spurs of Various Growths on a Biennially and on an Annually Bearing Wealthy Tree.

	Biennial					Annual				
Growth (cm.)	1916	1917	1918	1919	1920	1916	1917	1918	1919	1920
0.1-0.5	88.4	6.7	86.7	0	100.0	53.5	26.3	62.5	78.0	73.2
0.6-1.0	75.6	0	95.0	0	99.2	25.8	38.4	74.0	82.9	86.9
1.1-1.5	83.3	0	85.0	0	95.7	20.0	44.4	69.4	65.0	92.6
1.6-2.0	80.0	0	92.9	0	100.0	28.6	66.7	63.6	80.0	100.0
2.1-3.0	88.5	0	73.7	--	96.8	33.3	28.6	58.3	66.7	100.0
3.1-4.0	85.5	0	70.0	0	100.0	50.0	60.0	63.6	100.0	100.0
4.1-5.0	86.0	0	83.0	--	100.0	50.0	60.0	66.7	100.0	100.0
5.1-6.0	66.7	0	100.0	--	100.0	--	57.2	50.0	80.0	100.0
6.1-7.0	75.0	0	100.0	--	100.0	33.3	85.7	100.0	100.0	100.0
7.1-8.0	100.0	--	100.0	--	100.0	50.0	28.6	33.3	100.0	100.0
8.1-9.0	--	--	100.0	--	--	--	80.0	33.3	100.0	--
9.1-10.0	100.0	--	100.0	--	--	50.0	62.5	--	100.0	100.0

has borne with considerable regularity each year. Here again there appears a tendency toward mass behavior, to a considerable degree independent of the growth of the individual spur. In the biennial bearing tree this tendency is naturally the more pronounced; in 1917 almost no fruit buds were formed by any of the spurs studied, regardless of the growth they made, and in 1919 there were practically no spurs to be considered, for nearly all spurs studied were bearing. The apparent discrepancy between the 1918 and 1919 figures is explained by a few instances of consecutive bearing. Again it is emphasized that no measurements taken for the bear-

ing year of any spur are included; these figures apply in every instance to non-bearing spurs.

By Branches.—The data in Table 5 are fairly representative of conditions on the annually bearing Wealthy and show clearly that its annual bearing is due in large measure to individuality in the behavior of the branches. Not all branches show the same uniformity exhibited by those selected; nevertheless there is in every case a pronounced tendency to bear or not to bear.

Table 5.—Performance Records of Individual Limbs on an Annually Bearing Wealthy Tree.

Branch	No. spurs examined	No. spurs blossoming			
		1917	1918	1919	1920
A	21	0	18	0	21
B	14	12	0	14	0
C	43	2	33	1	43
D	30	2	0	30	0

Table 6 records performances of individual spurs on two branches of the same tree, one branch alternating with the other. There is little relation between growth and fruit bud formation in such cases as these, though, to be sure, the very short growths are few. Spurs 240, 241, 243 and 123, which failed to form fruit buds with the others, did not form them for the off year. This occurrence, though not invariable, appears to be more common than the opposite and points to a lack of complete independence.

Two branches, each of half-inch diameter, arising at points six inches apart on the same limb of a Jonathan tree, yielded the data recorded in Table 7. Every spur is included. These were young branches selected at random; several of the spurs on Branch A arose on 1917 wood. Neither of these limbs has borne biennially and in both cases the spur growth of the year preceding bearing is greater than that of the year which was not characterized by fruit bud formation. Nevertheless, large growth in the first of the two vegetative years, as exemplified in spurs A8(1918) and B7-(1919) did not result in fruit bud formation, though in the following year very short growths, as represented by A2(1919) and B6-(1920) were accompanied by fruit bud formation.

By Year of Origin.—Uncomplicated by previous history, spurs in their first year as individuals, if they be autonomous, should

present in their performance some indication of that condition. If, on the other hand, they depend somewhat on conditions farther back in the tree, more fruit bud formation should occur in spurs arising during the off year. Table 8 shows the first year performance of all Wealthy spurs measured. Under conditions presented here, spurs arising during the off year are likely to form fruit buds regardless of their growth and those arising during the bearing year are unlikely to form fruit buds, regardless of their growth.

Another way of stating essentially the same fact is shown by the arrangement used in Table 9. This shows the date of the initial blossoming of all spurs studied. Were the spur completely autonomous there should be a uniform yearly rate; the marked alternation actually shown is therefore particularly significant.

By Departures from Alternation.—In the cases of successive blossoming observed in Wealthy, the second blossoming occurred in the bearing year in 71 per cent of the total number. This means

Table 6.—Performance Records of Individual Spurs on Two Limbs of an Annually Bearing Wealthy Tree.

(*Growth in cm. F = blossoming, L = non-blossoming*)

Spur No.	1918	1919	1920	1921	Spur No.	1918	1919	1920	1921
230	.7	F	5.3	F	109	F	.7	F	L
231	1.2	F	2.0	F	110	F	.7	F	L
232	6.7	F	3.2	F	111	F	.3	F	L
233	.8	F	.8	F	112	F	.8	F	L
234	1.5	F	.7	F	113	F	.6	F	L
235	1.5	F	2.9	F	114	F	.4	F	L
236	1.2	F	.9	F	115	F	.4	F	L
237	1.5	F	.6	F	116	F	.8	F	L
238	1.3	F	1.7	F	117	F	.8	F	L
239	.5	F	3.3	F	118	F	.5	F	L
240	1.0	1.1	2.6	F	119	F	1.5	F	L
241	.8	.8	1.8	F	120	F	9.8	F	L
242	1.1	F	1.1	F	121	F	5.3	F	L
243	.6	1.7	6.2	F	122	F	1.7	F	L
244	.5	F	.2	F	123	8.6	1.5	F	L
245	4.0	F	3.4	F	124	F	2.4	F	L
246	5.3	F	.8	F	125	F	1.6	F	L
247	.5	F	2.5	F	126	F	9.0	F	L
248	.5	F	.9	F	127	F	1.7	F	L
249	2.3	F	1.1	F	128	F	1.1	F	L
250	.3	F	.5	F	129	F	6.6	F	L

that the spurs blossoming in the off year have much better chances of forming fruit buds immediately than those that blossom in the bearing year.

Still further evidence of a general influence affecting fruit bud formation lies in the growths of non-bearing spurs in a crop year as compared with those made in an off year. If the general draft of the crop have any effect it should be reflected in the growth of the non-bearing spurs at that time. Data from Gano, Jonathan and Wealthy show an almost invariable increase and decrease of vegetative growth inversely with the crop (see Table 10). It is least pronounced in Jonathan, where the alternation of crops is less pronounced. Comparison between varieties shows, as for example between 1918 and 1919, that the growths of two varieties go upward and that of the other downward, in keeping with the crops, precluding the possibility of weather influences controlling this increase and decrease.

Unsupported, these data would be open to the objection that the spurs not bearing in the crop year are chiefly barren spurs whose growth, always small, is submerged by the figures for the prolific spurs in the off year but constitutes nearly all the figures

TABLE 7.—PERFORMANCE RECORDS OF INDIVIDUAL SPURS ON TWO BRANCHES ARISING FROM THE SAME LIMB ON A JONATHAN TREE.

(*Growth in cm. F = blossoming, L = non-blossoming*)

	1918	1919	1920	1921
Branch A 1	.5	4.3	F	L
2	--	.2	F	L
3	.3	1.4	F	L
4	.3	1.0	F	F
5	.5	2.6	F	L
6	.2	.7	F	L
7	.6	1.6	F	L
8	1.0	3.7	F	L
Branch B 1	--	.5	1.0	F
2	F	.7	.6	F
3	F	.5	1.7	F
4	F	.8	1.7	F
5	F	.3	.5	F
6	F	.3	.3	F
7	F	2.0	6.3	F
8	F	.5	4.0	F
9	F	.4	.4	F
10	F	.4	1.0	F

for the crop year. Though no spur which had not blossomed at least once was recorded, as an additional check, all cases in which a spur after once blossoming had failed to follow the usual alternation were tabulated for Gano.

If there is any general influence affecting fruit bud formation it should be more effective toward bringing these barren spurs back to bearing in the crop year than in the off year. If, in addition, consecutive barrenness arise from failure to bear in the crop year, this same general influence should act to prevent fruit bud formation for blossoming in the off year. Consequently there should be more cases of three- and five-year successions of sterility than of two- and four-year respectively. If, on the other hand, there is no general influence, the frequency distribution should be

TABLE 8.—PERCENTAGE OF FRUIT BUD FORMATION ON WEALTHY SPURS DURING THEIR FIRST YEAR.

Growth (cm.)	0.1-0.5	0.6-1.0	1.1-1.5	1.6-2.0	2.1-3.0	3.1-4.0	4.1-5.0	5.1-6.0	6.1-7.0	7.1-8.0	8.1-9.0	9.1-10.0
Biennial Bearing Tree												
Off Year	70	71	69	80	92	100	50	100	75	100	--	67
Bearing Year	5	0	0	--	0	0	--	--	0	--	--	0
Regular Bearing Tree												
Off Year (for branch)	83	91	100	0	100	50	100	--	100	--	--	100
Bearing Year (for branch)	8	0	0	0	--	--	--	0	--	0	0	--
Combined												
Off Year	76	76	76	57	93	75	67	100	83	100	--	75
Bearing year	6	0	0	0	0	0	--	0	0	0	0	0

in uniformly descending order, the two-year cases being most frequent. The actual distribution found was: two years, 37; three years, 115; four years, 6; five years, 9.

Still closer analysis lends further support. The two- and four-year cases originated practically equally from bearing in the off year and from failure to bear in the crop year. Consequently, when combined and averaged they have little significance. However, with the growth segregated into crop year and off year, that in the crop year is found to average 1.97 cm. and in the off year 2.30 cm. The three- and five-year cases originated almost entirely from failure to bear in the crop year. Therefore their growths, if there be assumed a general influence outside the individual spurs, should show alter-

nate decreases and increases, inverse to the crop of the tree. In the three-year cases, starting with the off year, the average growths were respectively 2.64; 0.91 and 1.37 cm.; for the five-year cases the average growths were, respectively: 1.1, 1.0, 1.1, 0.5, and 0.7, showing in both classes a rhythm inverse to the crop. In all cases, the growth averages less in the crop year.

A still more rigid test is secured by assembling cases of consecutive unfruitfulness and averaging their growths with all growths accompanying fruit bud formation eliminated; these figures represent purely vegetative growths resulting only in leaf bud formation. For the consecutive years of most marked crop alter-

TABLE 9.—PERCENTAGES OF INITIAL BLOSSOMING BY YEARS IN SPURS OF GANO, WEALTHY, AND JONATHAN.

	Gano	Wealthy	Jonathan
1906	1.2	----	0.2
1907	0.6	----	0.9
1908	0.8	----	1.6
1909	1.0	----	1.6
1910	3.8	----	2.9
1911	1.8	0.8	6.8
1912	14.8	0.8	9.5
1913	3.6	3.0	16.5
1914	22.6	0.4	9.5
1915	3.2	3.4	19.6
1916	40.2	1.1	7.1
1917	0.4	49.1	17.1
1918	5.8	0.4	6.0
1919	0.2	35.4	1.3
1920	----	0.0	----
1921	----	5.8	----

nation these averages, beginning with the off year, are respectively: 1.19 cm., 0.96 cm., 1.15 cm. and 0.89 cm. If the last year of the unfruitful succession be included—the year before resumption of bearing—these differences are accentuated, viz.: 1.66 cm., 1.03 cm., 3.28 cm. and 0.88 cm. However, even with these omitted, the effect on the purely vegetative growth is interesting.

An Annually Bearing Limb.—To complete the statistical analysis, data from certain spurs on one limb of the annually bearing Wealthy are assembled in Table 11. These spurs have histories tracing back at least to 1914; most of them are older. This limb

is characterized by a tendency to bear annually. That this is an acquired tendency is shown by the increase from 1914 to 1919 in the number of spurs blossoming, a rise from one in the former year to nine in the latter. The proportion of cases of fruit bud formation in successive years is unusual for this variety. Even here the relationship between growth and fruit bud formation is not sharply defined and is revealed only by a general tendency toward increased growth as the spurs approached a fruitful condition.

TABLE 10.—GROWTH OF NON-BLOSSOMING SPURS IN RELATION TO THE PERCENTAGE OF SPURS BLOSSOMING IN THE SAME YEAR.

	1920	1919	1918	1917	1916	1915	1914
Gano							
Growth (cm.)	----	1.91	0.85	3.23	1.27	2.79	1.15
Crop (per cent)	----	*3.8*	*64.4*	*1.2*	*79.3*	*6.2*	*55.3*
Jonathan							
Growth (cm.)	----	0.81	0.76	1.54	1.96	1.20	1.35
Crop (per cent)	----	*14.4*	*31.5*	*55.2*	*21.3*	*55.0*	*24.2*
Wealthy							
Growth (cm.)	1.26	1.21	1.45	1.19	1.79	0.74	1.23
Crop (per cent)	*0.3*	*89.7*	*0.3*	*65.2*	*2.1*	*9.4*	*2.6*

DISCUSSION

Apparently, then, the data presented show, on the one hand a relation between spur growth and performance and on the other hand little or none of such relation. However, they are not irreconcilable. They reflect different conditions. Under certain conditions practically all spurs either form fruit buds or they do not; under other conditions some spurs form fruit buds while others, intermixed with them, do not. In the latter case the correlation between growth and fruit bud formation attains some importance. Spurs showing several successive years of unfruitfulness have a tendency toward increased growth in the year of fruit bud formation. This accounts for a little more of the correlation. Combined in massed figures these two tendencies establish the correlation as shown in Table 1.

However, the spurs that are making successive vegetative growths show a tendency toward uniformity even in the amount of this growth, as shown in Table 7. This suggests strongly that the relationship between growth and performance is a parallel

manifestation of the same or related influences and not in itself a cause and effect relationship.

The succession of units possible in performance is most striking. On the one extreme is the tree (Table 4); next smaller, the scaffold limb (Table 6); still in descending order, the branch (Table 7) and finally the spur (Table 11). This points to the probable importance of influences farther back in the tree than the spurs in promoting fruit bud formation. The influence must be strong in some cases, causing general uniformity, either in fruitfulness or in unfruitfulness. In other cases it may be less positive

TABLE 11.—PERFORMANCE RECORD OF INDIVIDUAL SPURS ON A BRANCH OF AN ANNUALLY BEARING WEALTHY TREE.

(*Growth in cm. F = blossoming, L = non-blossoming*)

Spur No.	1914	1915	1916	1917	1918	1919	1920	1921
169	.7	1.3	6.2	.8	F	.6	F	L
170	1.2	2.3	9.1	F	3.8	F	1.0	F
172	.6	F	9.4	8.0	3.5	1.3	1.4	F
173	1.0	.9	F	7.9	4.2	F	.2	L
174	.7	1.4	F	2.1	.8	F	.5	F
177	1.2	1.0	6.1	F	F	F	.7	F
178	.5	4.9	.5	3.9	.6	F	1.1	F
180	.5	.6	6.2	6.4	F	1.0	1.3	F
181	.5	.5	.7	.6	.5	F	.8	F
183	.2	.2	.4	.3	F	F	F	L
184	.5	1.1	2.0	5.7	1.5	F	.4	L
186	.4	.4	.7	.8	F	F	.3	L
187	F	.5	3.1	9.3	F	.4	F	L
188	.9	.4	.5	F	.4	.5	F	L
191	.5	.6	2.5	1.1	F	.8	F	F

and the performance of the individual spur determined largely by conditions within the spur itself (Table 11).

Evidence from Chemical Analysis.—Table 12 records chemical analyses of spurs and of bark from the scaffold limbs of bearing and non-bearing York trees. Since these data represent part of the material which will appear in a subsequent bulletin now in preparation, no attempt is made here to discuss their significance in detail, though it may be of interest to note that the bark even on the scaffold limbs of a tree in full bearing contains as high percentages of potassium as the spurs, the nitrogen percentage content is only half of that in the spurs and the phosphorus percentage content

is at times much less, but in June of the bearing year actually greater in the bark than in the spurs.

Two points, however, should be mentioned for their possible bearing here. Firstly, the essential similarity in nitrogen content of the bark and the marked difference in this same constituent in the spurs, as between bearing and non-bearing trees is at least interesting. The second point is the comparison of starch contents which are distinctly different in the bearing and non-bearing years and vary in the bark in the same manner as in the spurs. This offers clear evidence that in this respect a large part of the aerial portion of the tree is acting as a unit. The starch content of the bark may not affect that of the spurs; both may depend on the same condition in the tree as a whole. In other words, the circum-

TABLE 12.—THE CHEMICAL COMPOSITION OF BARK AND SPURS FROM BEARING AND NON-BEARING YORK TREES.

	Dry Weight	Reducing Sugars (Per cent dry weight)	Starch (Per cent dry weight)	Ash (Per cent dry weight)	K (Per cent dry weight)	P (Per cent dry weight)	N (Per cent dry weight)
Trees in Bearing							
Bark							
May 22	43.4	1.48	0.11	7.97	.621	.060	0.58
June 19	47.9	1.32	0.00	9.91	.570	.145	0.58
Sept. 6	44.9	1.87	2.53	10.76	.457	.110	0.52
Nov. 20	44.1	2.68	1.58	12.35	.498	.098	0.69
Spurs							
May 22	40.2	.79	0.68	9.73	.678	.170	1.020
June 19	44.4	1.26	0.00	6.44	.554	.140	0.916
Sept. 6	46.7	1.21	2.88	7.97	.408	.155	1.030
Nov. 20	48.4	2.95	1.08	9.05	.489	.222	1.220
Non-Bearing Trees							
Bark							
May 27	42.1	1.38	0.72	11.62	.601	.083	0.56
June 24	43.5	.94	2.30	7.85	.558	.084	0.55
Sept. 20	48.1	.90	3.19	8.87	.461	.113	0.58
Dec. 3	53.8	4.22	1.91	10.28	.587	.110	0.72
Spurs							
May 27	45.6	1.17	0.92	8.98	.593	.123	0.773
June 24	49.4	.92	2.88	6.67	.516	.227	0.960
Sept. 20	53.9	.79	2.75	10.38	.445	.202	0.950
Dec. 3	44.7	2.78	1.51	8.85	.539	.233	1.090

stance which prevents starch accumulation in the spurs may likewise prevent starch accumulation in the bark when the majority of spurs are bearing fruit and it might be supposed that the large amount of developing fruit which the tree is bearing utilizes all the carbohydrates that the usually diminished leaf area of the bearing tree can manufacture and consequently diminishes the supply reaching the regions of storage. Since starch accumulation does not occur in the bark of these trees at the time of fruit bud differentiation when the tree is in its bearing year it is not surprising that starch accumulation is also absent in the relatively few spurs that are not bearing fruit and particularly in newly formed spurs on second year wood.

Hartig[9] found that previous to the seed year in the beech and oak large amounts of starch were stored in the medullary rays of the wood. In non-bearing years the starch stored in the two youngest annual rings was reduced to about half after the middle of June, but the supply was replenished in October; in the seed bearing year the starch content of the entire wood was reduced to a minimum, consuming the accumulation of eight years; furthermore nearly all the nitrogen disappeared from both wood and bark. Hartig concluded that the food supply of the buds was derived from local accumulations, that the activity of the cambium utilized only a very small amount of the starch stored in the wood, but that the accumulation of surplus reserves over a period of eight years was used in seed production. "In many trees, for example elms and fruit trees," he states, "a seed year usually follows a year of rest in which surpluses are accumulated; in other kinds of trees seed years recur only after three, five or even ten years."

These findings are important since they indicate that in the beech and oak, as well as the alternate bearing apple, the tree acts more or less as a unit; they suggest that the starch content of apple wood may be significant and they imply a rather direct relation of the reserve starch in the trunk and branches to the fruitful condition of the tree as a whole. If Hartig's surmise that the starch accumulations in the trunk are used for seed production be correct, the question of the passage of carbohydrates up the trunk must be studied from a new point of view. In the beech, for example, no significant upward translocation of carbohydrates would occur eight years out of nine. Very materially different results might be obtained from investigating trees in the bearing year

than in the off year and a consideration of the condition of the material used for experimental purposes might go far to reconcile the conflicting reports on the upward translocation of carbohydrates.

Evidence from Diameter Growth.—The influence of crop production on the older parts of the tree is shown not merely by the chemical analyses just presented, but also by the measurements of wood growth shown in Table 13. The greater width of annual rings in years when no crop was borne cannot be attributed to variations in climatic factors or in soil conditions since the two branches studied were taken from the same tree; branch C bore fruit in even years while branch D bore fruit in odd years. This

TABLE 13.—WIDTH OF ANNUAL RINGS (IN MILLIMETERS) ON TWO BRANCHES OF A WEALTHY TREE.

	Branch C (bearing in even years)		Branch D (bearing in odd years)	
	Secton 3.3 cm. in diameter	Section 2.1 cm. in diameter	Section 3.7 cm. in diameter	Section 2.3 cm. in diameter
1917	1.6	1.9	0.5	1.2
1918	0.7	0.8	1.2	0.5
1919	1.3	2.3	0.3	0.3
1920	0.9	0.8	0.4	1.5

relationship has not been studied sufficiently to warrant an assertion of its universal occurrence, though the same correlation has been observed here in old Ben Davis spurs and McCue[10] reports, "In the alternate bearing [apple] trees, the year of production seems to succeed a year of relatively great increase in trunk increment."

SIGNIFICANCE

A priori application of these facts to fruit bud formation in the apple would be unjustified and is not attempted here. However, enough evidence is available to indicate that though conditions within the spur are always important and frequently decisive, conditions in the tree back of the spur are also important and frequently decisive of the spur's performance. It is shown here that the spur or the whole tree or branches may be units and that the individual spur is influenced, sometimes at least, by the performance of the other spurs.

How indirect this influence is, through effects on near or on remote portions of the tree, is not yet determined. It is shown that the collective performance of the spurs has an influence on rather remote parts of the scaffold limb. Whether the remote parts have an influence on the spurs is not yet shown definitely. The data presented show that the factors influencing fruit bud differentiation are localized narrowly at times, widely at times. In any case, careful investigation of the factors determining fruit bud differentiation should not be confined to the spur alone.

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INVESTIGATIONS ON THE HARDENING PROCESS IN VEGETABLE PLANTS

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INVESTIGATIONS ON THE HARDENING PROCESS IN VEGETABLE PLANTS

J. T. Rosa, Jr.

This study was undertaken as one phase of a project on the transplanting of vegetable plants. The hardening process, whereby vegetable plants are made more resistant to cold and better able to withstand the hardships of transplanting from greenhouse or hotbed to the open field, is of great importance in the practice of growing certain vegetables which are customarily transplanted. In the production of early crops, hardiness also is especially important because of the low temperatures to which transplanted plants are exposed upon their removal to the field in early spring.

Furthermore, since the hardening process in vegetable plants results in a condition of *acquired hardiness,* developed rather quickly by subjecting plants to certain treatments, experiments with such material throw considerable light on the general problem of cold resistance in plants. This question, in connection with that of the nature of the process of killing of plants by low temperature, has received the attention of numerous investigators during the past one hundred years. Though much information has been accumulated, the whole problem is in a somewhat undefined state. It is the purpose of this paper to propose a theory comprehensive enough to explain satisfactorily the known facts as to the cold-resistance of living plants and to present data on the nature of the response of plant-tissues to treatments which result in increased hardiness. The injurious effects of temperature slightly above the freezing point on the growth of plants are not dealt with in this paper.

REVIEW OF LITERATURE.

The Physical Process of Freezing in Plants.—An early theory as to killing of plants by cold, advanced by Duhamel and Buffon[27*] in 1737, held that death was due to the rupture of the tissues, bursting of the plant cells, by the expansion of ice crystals forming within the cells upon freezing.

*This and subsequent superscript numerals refer to literature cited in the Bibliography.

NOTE.—Also submitted to the Faculty of the Graduate School of the University of Missouri as a thesis in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

Geoppert[32] in 1829, found that ice formation upon freezing of plant tissue was not confined to the interior of the cells and concluded that the killing of plants by cold was not due to cell rupture. A few years later, Morren[73] substantiated Geoppert's conclusion in that he found no organ of the plant torn by freezing. He considered that injury from freezing was due mostly to the separation of air from the plant sap. In 1860, Sachs[105] using improved technique, observed that in the process of freezing, water was withdrawn from the cell and ice-crystals formed for the most part in intercellular spaces.

In 1860, Nageli[89] showed by calculation, that the expansion caused by freezing all the water in the cell, would not be sufficient to cause a rupture of the cell-wall. Prillieux[99] in 1869, found that water was extruded from the cells upon freezing. Müller-Thurgau[74] found that ice formed within the cell to some extent, when the lowering of the temperature was very rapid, but in case of gradual cooling to the point of ice formation as in nature, the crystals were found exclusively in the intercellular spaces. Wiegand[28] noted similar results upon freezing *Spirogyra* and *Nitella*. Thus the finding of ice crystals within the cells by earlier investigators, who froze the plant tissue very quickly, is explained. Cavallero[19] confirmed the work of the German writers, as he found that cell rupture in winter was very rare, the cells themselves never freezing, though ice formation occurred in the intercellular spaces of both hardy and tender plants.

Geoppert[32] noted that plants which were frozen to death lost water rapidly upon thawing. Sachs[106] observed that upon thawing, water remained in the intercellular spaces until reabsorbed by the cells or lost by evaporation. Under certain conditions considerable time elapsed before the water was reabsorbed and the protoplast regained its turgid condition. Prillieux[100] describes experiments on freezing pieces of potato and beet, showing that water was lost from these tissues upon thawing. He recognized also that water was lost from the tissues while still frozen, by evaporation from the surface of the ice crystals.

Prunet[101] found that moisture is lost by evaporation from the surface of the leaf on thawing, rather than by normal transpiration through the stomata.

Abbe[1] stated that as plant tissues were cooled, water exuded from the cells into the intercellular spaces, and after sufficient under-

cooling, this water froze. The concentrated sap left within the cell did not freeze until cooled still lower.

If the water is withdrawn from the cell before freezing in the intercellular spaces, it is important to find how this withdrawal takes place. Wiegand[131] offered two theories to account for cellular water loss upon freezing, "extrusion" and "attraction."

Extrusion.—This hypothesis is that the cell actively gives up water at low temperature by contraction and squeezing. Greeley[34] showed that cooling to near 0°C. caused *Stentor* to contract and become cyst-like. Under the same conditions *Spirogyra* became much plasmolyzed. Livingston showed that when mounted in oil, this plasmolysis was accompanied by extrusion of droplets of water. Wiegand thought that the most probable explanation of this method of water loss from the cell was by change in permeability of the protoplast to the sap solute. A recent report by Pantanelli[96] supports this idea. In experiments with the pericarp of the mandarin cooled almost to the freezing point of this material (–6°C.) he observed a progressive increase in cellular permeability, as shown by rapid loss of water and exomosis of substances from the tissue. Osterhout[93] has shown that freezing as well as treatment by various anesthetics, greatly increases cellular permeability.

Attraction.—Wiegand[139] considered his so-called attraction theory as the more probable explanation of water withdrawal from the cell. Thus in ordinary plant tissue Wiegand pictured the following arrangement:

(1) A film of pure, or nearly pure, water adhering to the outer surface of the cell wall, bordering on the intercellular spaces.

(2) The inert cell-wall cellulose material filled with water of imbibition, which is continuous with that of the protoplast.

(3) A more or less narrow strip of protoplasm adhering closely to the inner surface of the cell wall and containing water of imbibition, continuous with that of the vacuole.

(4) The vacuole, containing an aqueous solution of salts, sugars and other substances.

Normally this system is in equilibrium. According to Wiegand, upon lowering the temperature below the freezing point, the film of pure water on the outer surface of the cell walls freezes first. The tendency will then be to restore equilibrium by drawing water from the interior of the cell to replace the surface film. This water will be drawn first from the cell wall, which in turn will draw on the

protoplast, which in turn will draw on the sap in the vacuole. The water of the vacuole is held by the force of solution alone, whereas the cell wall and protoplasm hold water by the stronger force of imbibition. If the temperature remains constant, this readjustment will continue until the force of crystallization is equalled by the increased force with which the remaining water is held within the cell. After equilibrium is established between the forces of crystallization and the water-retaining power of the cell, at any given temperature, no more water freezes unless the temperature is lowered further, thereby increasing the force of crystallization. However, since the force with which the remaining water is held increases rapidly with the progressive loss of water, Wiegand predicted that the amount of water frozen at each successive degree for which the temperature is lowered would be smaller and smaller. This was shown to be approximately true by the experiments of Müller-Thurgau[74] with apples, and the work of McCool and Millar[80] with green plants suggests the same conclusion. Bouyoucos[11] working with soils, found that little more water was frozen at –78°C. than at –6°C.

The foregoing hypothesis as to the conditions under which ice is formed in living plant tissue has been substantiated by work of

EFFECT OF GLUCOSE SOLUTIONS ON COLD RESISTANCE IN SECTIONS OF RED CABBAGE LEAVES.

Temperature	Concentration of Solution.						
	2M	M	M/2	M/4	M/8	M/16	Water
- 5.2°C.	all	living					½ cells alive
- 7.8°C.	all	living			¼ cells alive	single cells alive	all dead
-11.1°C.	all	living		½ cells alive	single cells alive	all dead	
-17.3°C.	all	living	½ cells alive	single cells alive	all dead		
-22.0°C.	all	living	single cells alive	all dead			
-32°C.	½ cells alive	single cells alive	all dead				

Maximow.[66] In extensive experiments with red cabbage and *Tradescantia discolor* he found a marked "protective" action when sections were frozen in solutions of salts, sugars, and other organic materials, provided the substance used was not toxic and its eutectic point did not lie too near the freezing point. Although the conditions of Maximow's experiments cannot be duplicated in nature, his results are of interest. The following table, taken from Maximow's work, is typical of the results he secured.

Evidently red cabbage cells, which ordinarily are killed at a little below –5°C., survive a temperature as low as –32°C. in 2–mol. glucose solution. Maximow concluded that this apparent protective action of the solution could not be explained by the depression of the freezing point, since the resistance to cold always increased with the strength of the solution much more rapidly than this depression. The degree of protection was found however, to be closely related to the eutectic point of the solution, substances having a high eutectic point showing no protective effect. Isotonic solutions of different substances with low eutectic points possessed nearly the same degree of protective action. Maximow found no relation between the rate of penetration of the protective substance and the degree of protection afforded, and that just as much protective action was exerted by the various solutions when sections were immersed in them and frozen immediately, as when the tissue had been soaked several hours in the solution before freezing. (Hence there could have been no effect on cell sap concentration or in preventing precipitation of the cell proteins.)

If we consider Maximow's work in connection with Wiegand's hypothesis of freezing, we have a condition differing from the usual, in that the film of pure water on the outer surface of the cell wall is replaced by a more or less concentrated solution. In the first place, this would lower the initial freezing point somewhat. More important still, the fact that the cell is surrounded by a more or less concentrated solution should mean that in the process of water withdrawal and ice formation at any given temperature, a state of equilibrium between the ice-crystal and the cell system would be reached sooner than in the case of cells not surrounded by such solutions, if the "attraction" theory of water loss as advanced by Wiegand be accepted. Somewhat less water would be frozen at a given temperature in the cells of tissue immersed in salt or sugar solution. If the amount of water frozen per degree of temperature lowering becomes smaller and smaller, it would be necessary for a "protective" solution to

effect a very small reduction in the amount of water freezing at the lower temperatures to enable the cell to stand cooling several degrees below the usual death-point. Recent work by Vass (122) on bacteria leads to the same conclusion. He found a distinct protective action exerted by glycerine and glucose solutions on freezing bacteria, as shown in the following table.

VASS' RESULTS ON FREEZING OF BACTERIA AT -5°C.

Strength of solution	Percent of bacteria killed	
	In glycerine	In glucose
0.00 (water)	96	—
0.01%	92	98
0.05%	87	95
0.1	41	89
0.5	45	74
1.0	0	58
5.0	0	35
10.0	0	4

Vass concluded, in agreement with Maximow, that the protective action of these solutions was due to their power to keep a film of unfrozen water in contact with the outer layer of the protoplast, the plasma membrane.

Nature of the killing of plant-tissue by cold.—From the foregoing review, the evidence appears conclusive that cell rupture cannot be the cause of killing of plants by cold, but that water-loss from the cells by ice formation in the intercellular spaces is an invariable accompaniment in such killing. According to Müller-Thurgau,[76] Molisch[71] and others, death cannot be due directly to absolute cold, and there is little if any evidence of death due to shock or other reaction attributable to "cold-rigor." Thus, both Müller-Thurgau[76] and Voightlander[123] showed that plant tissues could be undercooled several degrees below the freezing point without injury as long as ice formation did not take place. Wright and Taylor[122] have recently shown that potatoes can be cooled several degrees below their freezing point and warmed up again without injury, provided no ice formation took place. However, jarring undercooled potatoes caused ice-formation to take place and resulted in typical frost injury.

Chandler[20] found evidence that tender plants exposed to temperature slightly below freezing when the surface of the leaves was wet, killed to a greater extent than if the leaves were dry. This result is explained by Harvey's "injection" theory, according to which undercooled tissues are caused to freeze in spots where droplets of free water on the surface crystallize and inoculate the tissue just beneath with the growing crystals.

These facts strengthen the view that killing by cold depends on ice formation, rather than on the effect of low temperature in itself. Just how death is caused by the freezing process is a question of interest. Four distinct theories have been advanced.

(*a*) *Direct result of water loss—" desiccation."*—Müller-Thurgau[74] believed that death was the direct result of the water loss, that is, death ensues when so many molecules of water are withdrawn from the protoplast that its living structure is permanently destroyed. Wiegand[131] concurred in this hypothesis, with the additional suggestion that "probably every cell has its critical point, beyond which water withdrawal causes death." Cavallero[19] attributed killing to the wilting upon thawing, due to rapid evaporation of melting ice in the intercellular spaces. He mentioned an opinion generally held by practical gardeners, that under conditions favoring slow thawing or slow evaporation, such as shade or moisture, severe injury to the plant might be prevented by the re-entry of water into the cells. However, Müller-Thurgau[74] and later Molisch[71] found no difference in extent of killing, between rapid and slow thawing. Chandler[20] also concluded from a considerable number of experiments that the rate of thawing generally had no influence on death from freezing. We should distinguish here between the loss of water from the cell and its loss from the plant as a whole. If the cells are killed directly by loss of water on freezing, or if they are killed by changes taking place as a result of this water loss, then the rate of thawing would have no effect on the killing. However plants capable of standing some ice formation within their tissues, would take back more of this water if thawed slowly, whereas they might lose the most of it if thawed rapidly. This explains two things, the wilted condition often observed in frozen plants upon thawing, and the cumulative effect of successive freezing and thawing, whereby a fraction of the plant's water content is permanently lost by the plant on each thawing.

Nelson[90] thought that rapid loss of moisture was the principal cause of winter-killing of shrubs in high, dry sections. Kylin[56] in a recent study of the cold resistance of marine algae, concluded that death from cold was conditional upon actual formation of ice and that such death was primarily due to withdrawal of water from the cell. Matruchot and Molliard[64] described the successive changes in arrangement of the chromatin strands of the nuclei in leaf cells of the snowdrop subjected to freezing temperatures. They stated that water was withdrawn from the protoplast and nuclear material of the cell, and that this continued if the temperature was sufficiently low,

until these portions of the cells contained less water than the minimum necessary to vitality. They[63] also subjected plant tissue to freezing, to drying and to the action of solutions of high osmotic concentrations. They observed a marked parallelism in the effects of these treatments, hence they concurred with Molisch and Müller-Thurgau in that death of the cell was due to rapid loss of water. Adams[3] working with moist seeds, observed that in freezing, water was drawn from the cells and solidified in the intercellular spaces and if the freezing did not go too far, upon melting the water was reabsorbed slowly, without injury having been done to the cells.

Wiegand[129] made extensive observations on the freezing of leaves and buds. In buds in winter: "Ice was always found in broad, prismatic crystals arranged perpendicularly to the excreting surface and usually formed a single continuous layer throughout the mesophyl of the scale or leaf, to accommodate which the cells were often separated a considerable distance. The cells near the ice mass having lost their water, were in a state of collapse, but upon thawing they reabsorbed the water and resumed their normal condition." This was also true of evergreen leaves, in which he observed that ice crystals first lined the spaces of the spongy parenchyma, later filling these spaces and, in leaves of high water-content, the crystals fused into a sheet of ice completely separating the upper and lower portions.

In observations on thawing of frozen leaf sections, Wiegand noticed in hardy tissues, not killed by the freezing, that upon thawing the water was drawn back into the cells, but in tender tissues killed by the freezing process, water was not drawn back into the cells to any extent. Pantanelli[94] concluded that the suffrance of each cell is directly proportional to the outgo of water during cooling. He also attaches great importance to the condition of the roots with reference to ready water absorption in determining whether or not plant recovers from freezing.

(*b*) *Injury to the plasma membrane by water withdrawal.*—Maximow[66] concluded as a result of an extensive series of experiments, wherein sections of plants were frozen in solutions of various salts and inorganic materials, that killing by cold is not due to low temperature as such, but to physico-chemical changes set up in the colloids of the plasma membrane during ice formation therein. This is really a modification of Müller-Thurgau's theory, limiting the injurious effects of water-loss to the outer layers of the protoplast.

Chandler[20] also concluded from his exhaustive researches that

"killing from cold is more likely a mechanical injury due to withdrawal of water from the protoplasmic membrane than an injury resulting from a precipitation of proteins."

(*c*) *Protein precipitation through "salting out."*—Gorke[35] concluded that killing was due to irreversible precipitation of the proteins of the cell. He accounts for this precipitation by the greater concentration of the salts in the sap as water is withdrawn from the cell by formation of ice, since certain proteins are precipitated in strong salt solutions. He found that approximately ⅓ of the proteins were precipitated in frozen cereal plants. Gorke found also that hardiness of certain plants bears some relation to the ease with which their proteins were precipitated. In the tender begonia he obtained protein precipitation at –3°C., in winter rye at –15°C. and in pine needles at –40°C. Schaffnit[110] also concluded that protein precipitation was the cause of death. He found that the proteins of rye plants grown in the open at low temperature were not as easily precipitated upon freezing as those of tender greenhouse plants. The effect of low temperatures on the hardiness of plants grown in the open was ascribed to a transition from less stable to more stable forms of the proteins by splitting. He found that he could prevent the precipitation of proteins from the sap of tender greenhouse plants by addition of sugar, to which he ascribed a protective action against protein precipitation and consequently against injury of the plant from cold, although it was not proven that these two are always related.

Chandler[20] was rather disinclined to accept the idea of killing by "salting out" of proteins. He found that the hardiness of plants was increased by growing them in salt solutions, such as zinc sulphate, which is an excellent protein-coagulating agent. However, Chandler's work on this point cannot be held to disprove the protein-precipitation idea, since he showed no evidence that the protein-precipitating salts were taken up by the plant, or if they were taken up, that they existed in the plant in a form which would precipitate proteins upon concentration. However, the fact that Chandler did not find appreciable protein precipitation on freezing the extracted sap of apple twigs indicates that killing may not always be accompanied by protein precipitation, although his technique on this point may be open to question.

(*d*) *Protein precipitation by increase in acidity.*—Changes in color of plant sap due to change in reaction upon freezing are well

known. Gorke[35] noted an increase of acidity in sap upon freezing. He believed this was a factor in the precipitation of the plant proteins, since the acidity of the medium is important in determining the state of such colloidal materials.

Harvey,[42] in a recent paper dealing with cold injury to cabbage plants, extended this theory. He found definite evidence of increased acidity as a result of freezing cabbage plant juice, by measuring the hydrogen–ion concentration before, during and after freezing to definite temperatures. He noted protein precipitation when the actual acidity was increased from PH 5.65 to PH 5.26. It is especially interesting to note that Harvey found a similar increase in the acidity of juice expressed from leaves exposed to wilting, though he does not state if the leaves were wilted beyond recovery. Harvey demonstrated that if phosphoric acid was added to the expressed sap until the Hydrogen–ion concentration was increased as much as it would have been by freezing, a precipitation of the protein occurred, thus implying that the parallel effect of water loss by wilting or by freezing and addition of acid, was protein precipitation and death.

Harvey repeated Gorke's experiment on the precipitation of protein from expressed sap by freezing. Samples of juice were taken from hardened and not hardened cabbage plants and frozen to –4°C., a temperature which would kill the non-hardened, but not the hardened plants. It was found that 9.4 percent of the protein in the juice of the hardened plants was precipitated and 31.2 percent in the tender plants. Repeating the experiment and adding sufficient acid to change the reaction of the juice the same amount as it would be changed by freezing to –3°C. he found that 11 percent of the protein was precipitated in the juice of hardened, and 44 percent in tender plants. He also made complete analyses of hardened and tender cabbage plants, finding that of the water-soluble fraction of nitrogen about 35 percent was amino-nitrogen in hardened plants, and only 17 percent in tender plants, having about the same amount of water-soluble nitrogen. Harvey thought this increase in amino-nitrogen to be a very significant result of the hardening process, though he said it was not necessary that complete cheavage of the proteins to the amino acids should occur, to prevent their precipitation on freezing.

Relation of water-withdrawal from the cells to killing by cold.—No matter which agency is chiefly operative in the actual freezing and killing process, they all depend on the withdrawal of

water from the cell. Irreversible coagulation of colloids, such as protoplasm, is itself essentially a dehydration process. It is, then, by means of factors affecting water-withdrawal from the cell by ice-formation that the differential killing of plant tissues by low temperatures may be explained.

Schaffnit[110] classified plants in three groups, according to their cold-resistance and ability to withstand desiccation.

1. *Plants for which water is absolutely essential.* This we take to include such plants as tomatoes, which are killed once extensive ice formation actually takes place.

2. *Plants which withstand a certain degree of desiccation.* These would be such plants as the cabbage which can survive a certain amount of ice-formation in the tissues without injury. It is this group with which we are mostly concerned in discussions of hardening or cold-resistance.

3. *Those which withstand complete drying—seeds, spores, etc.*

This classification can be taken to include all plants, except those which are killed by cold above the freezing point. Such killing is probably due to inability to carry on their normal metabolic functions at low temperatures, as suggested by Molisch, rather than to direct effect of cold.

Relationship to cold resistance of factors influencing the water-retaining power of cells.—If the killing of plant tissue by cold is primarily due to water-withdrawal from the cells beyond a certain minimum point, then the difference between hardy and tender tissues may be ascribed largely to the relative water-retaining power of the cells in the two types of tissue.

There are two main forces concerned in the water-retaining power of plant cells. (1) Osmotic concentration, due to sap solutes in the vacuole, and (2) Imbibition, a force exerted by some constituents of the cell wall, nucleus, plastids, and especially by the colloidal cytoplasm. The importance of either of these forces in the water-retaining power of cells may be influenced by various factors.

Osmotic concentration and water-retaining power.—Since the freezing point of a solution is lowered in proportion to its molecular concentration, several workers have sought a correlation between cold resistance and the molecular concentration of the sap as measured by the depression of the freezing point.

Lindley[61] in reviewing the work of Morron and others in 1852,

was probably the first writer to connect the depression of the freezing point of the sap with cold resistance.

Chandler[20] directed much attention to the relation of osmotic concentration to hardiness, although he admitted that the force of imbibition may be the more important factor in the water-retaining power of plant tissue. He found in most cases that the hardier plants had the more concentrated sap. To explain the relation of a slight difference in freezing point depression to a considerable difference in hardiness, Chandler reasoned that, since in a solution containing one gram molecule the freezing point is –1.86°C., and in a M/2 solution, –0.93°C., in the latter solution at a temperature of –0.93°C. all the water would be unfrozen, at –1.86°C. one half would be unfrozen, and at –3.72°C. one-fourth would be unfrozen, and so on. If this held true for the water contained in a plant, the sap of which is equivalent to about one-half gram molecular concentration, we would then expect 75 percent of the water to be frozen at –3.72°C. However, Chandler's conjecture on this point does not apply in all cases since McCool and Millar found in their dilatometer experiments that nearly as much water is frozen at –4°C. in wheat plants having a freezing point depression of 1.107°C. as in corn plants having a depression of only 0.578°C.

Ohlweiler[92] in studying the effect of a late spring frost on vegetation at St. Louis, found that plants which showed the greater osmotic concentration of the sap were generally injured the least, although there were some exceptions. He found, for example, that in twelve species of *Magnolia*, the order of hardiness paralled the order of sap concentration fairly well. Harris and Popenoe[40] found that on the average, the hardier species of avocado had slightly the greater sap concentration. Lewis and Tuttle[59] working on evergreen leaves in Canada, found that in *Picea Canadensis*, the freezing point lowering varied only slightly from October to April, the maximum lowering being in March. In the bark of *Populus* and the leaves of *Linnaea* and *Pyrola*, the maximum depression of the freezing point was also found to be in March, after the coldest weather was over. The freezing point depression was found to parallel the accumulation of sugars during the winter months, the maximum sugar content being found April 2nd., just before spring growth started. They found little correlation between cold resistance and sap concentration, as measured by the depression of the freezing point. Pantanelli[95] likewise, was unable to establish a relation between osmotic concentration of the cell sap and resistance to cold.

Salmon and Fleming[109] found no relationship between sap concentration and winter hardiness in several common cereal crops in Kansas. Thus on November 27th., hardy Kharkov wheat gave a freezing point depression of 1.230°C. and tender Culberson oats 1.199°C. On December 17th., the freezing point depression of the wheat was 0.935°C. and of the oats 1.260°C. They explain these results by the supposition that oats are less able to secure sufficient water from the soil to supply that lost by transpiration, the ground being frozen at the time of the second determination. This resulted in water-depletion in the oat plants, giving a higher cryoscopic value to their sap.

Wiegand[131] thought osmotic concentration of plant sap to be of importance in relation to ice-formation at the inception of freezing only.

Imbibition and water-retaining power.—The term "imbibition" will be used in this paper in the general sense, as applying to the absorption of water by colloidal materials and the holding of water by finely divided solids by means of surface phenomena, such as adsorption, adhesion or molecular capillarity.

De Candolle[75] (quoted by Lindley in 1855) formulated the following laws of temperature in relation to plants:

"1. The power of the plant to resist low temperature is in inverse ratio of the water content.

"2. Hardiness is in direct proportion to the viscidity of the plant's fluids.

"3. Hardiness is in inverse ratio to the rapidity with which the fluids circulate.

"4. Tenderness is greater in proportion to the size of the cells."

Considering that De Candolle had few or no experimental data from which to draw conclusions, and that he wrote many years before the classical researches of Müller-Thurgau, his views on the resistance of plants to low temperature are remarkably near present conceptions.

Wiegand[131] considered that the force of imbibition was to a large extent the cause of the water-retaining power of plant cells. According to Pfeffer[140] this force increases with decreasing moisture content. Although Wiegand made no quantitative measurements, his theories were the result of keen observation and sound reasoning and are of very great importance to an understanding of the differential killing of plants by cold. He pointed out that the water of crystallization in frozen plant tissue was practically pure, sepa-

rating from the other cell constituents upon freezing. The progressive dehydration of the cell by the withdrawal of water to form ice crystals, was thought by Wiegand to increase the combined forces of osmosis and imbibition holding the remaining molecules of water. He advanced the hypothesis that the degree of cold necessary to form ice was proportional to the force which held the water in the tissues, which force (osmosis plus imbibition) was thought to depend largely on the water content. Wiegand believed that in succulent tissues of high water-content, most of the water would be frozen out near the initial freezing point and a smaller portion would be frozen in less succulent tissues.

Wiegand[129] observed that no apparent ice formation took place in the buds of *Quercus, Castanea, Hicorea, Juglans,* and *Fraximus,* at –18°C. The buds of these species were observed to differ from many others in which ice formation took place at a higher temperature by: (1) lower water content, (2) smaller cells, (3) thicker cell walls. He considered that these factors favored the retention of cell moisture by a relatively greater force of imbibition than in buds lacking such characteristics and in which ice forms at a higher temperature. Wiegand also observed that the ice crystals in frozen beets and potatoes were smaller near the periphery than in the center of these organs. The cells of the peripheral regions in these roots being smaller and poorer in water, were thought to have a greater capacity for retaining water against the formation of ice crystals.

Recent work by Parker[97] strengthens Wiegand's hypothesis that decreasing water content increases the force of imbibition. He found that finely divided materials in suspension held a considerable amount of water as capillary surface films, and the force with which this capillary water was held increased rapidly with decreasing moisture content. That moisture content has a marked influence on the force of imbibition is indicated also by the work of Reinke,[139] who found that a pressure of sixteen atmospheres would squeeze water from a frond of *Laminaria* when the moisture content was 73 percent, but when the moisture content was reduced to 48 percent, it required a pressure of 200 atmospheres to extract water.

If decreasing moisture content increases the force with which water is retained by plant cells, a direct connection is indicated between such water-retaining power and cold resistance, for several investigators working with a wide variety of plants have shown that hardiness is usually associated with low moisture content. Thus, Lindley[61] recognized the fact that decreasing the moisture content

tended to increase cold resistance and that the removal of some water in the "ripening process" made the plant's tissues better able to withstand cold. Detmer[26] stated that such parts of plants as are poor in water withstand low temperature best. He found that air-dry seeds of *Triticum* and *Pisum* germinated normally after exposure to temperature of –5° to –10°C., while turgid seeds were killed under the same conditions.

Gorke[35] noted that the more hardy plants had the greater percentage of dry matter and slightly lower sap freezing point. Schaffnit[110] found a gradation in the amount of dry matter in different varieties of wheat in direct proportion to their resistance to low temperature. He concluded that high dry-matter content was correlated with high frost resistance. Rivera[103] found that all cultural conditions which tended to increase the percentage of dry matter in wheat decreased the tendency to lodging and increased hardiness. Hedlund[44] found that under like cultural conditions, those varieties of winter wheat having a higher percentage of dry matter in autumn are generally more winter-hardy than those having a low percentage. He found also that cultural conditions that make for high percentage of dry matter favor winter hardiness. Hedlund attributed the high dry-matter content of hardy plants to their large carbohydrate content.

Shutt[114] found that a correlation existed between percentage of dry matter and hardiness in apple twigs. A set of samples gathered on the Canadian Experiment Farm in midwinter had moisture contents ranging from 45.1 percent in terminal parts of twigs of Yellow Transparent (hardy) to 51.59 percent in the same portion of the Blenheim Pippin (tender). He recommended the use of cultural practices to regulate the moisture content, as indicated by the degree of maturity in the fall. It is now a pretty well recognized fact that the ability of a variety of the apple to survive in Northern sections depends on its maturing thoroughly before winter—in other words, developing a condition of low moisture content and maximum water retaining power. Webber[127] and his co-workers observed after a very severe freeze in the citrus regions of California that trees and portions of trees which were dormant or inactive were much less injured than those actively growing and functioning. Trees which had been rather dry for some time also were more hardy than those recently irrigated while trees suffering badly from drought were injured worst.

Batchelor and Reed[5] found that winter-injury of the distal end of the branches of the Persian walnut in California could be pre-

vented by bringing the trees to early maturity by with-holding water, followed with heavy irrigation during the winter.

Johnson[51] found a marked seasonal increase in water content of peach buds in Maryland, correlated with the increased tenderness of buds in spring. The variety Greensboro had a lower water content than the Elberta, which is a tenderer variety. West and Edlefsen[128] also working on peach buds, pointed out that buds might escape injury from cold by under-cooling below the freezing point without ice formation, when the amount of moisture in the buds was small.

Chandler[20] and more recently Carrick[18] found that apple roots which had been allowed to absorb moisture for several hours were injured by cold a little more than normal roots, whereas partial drying increased their cold resistance.

Beach and Allen[6] found that drying apple twigs before freezing lessened the injury by cold. They also found that the hardier varieties of apples have the lower moisture content during the growing season but after prolonged freezes in winter, these hardy sorts may contain more moisture than tender varieties. In other words, the hardy twigs undergo a smaller water loss during freezing.

Salmon and Fleming[109] performed an interesting experiment with greenhouse-grown cereal plants, which demonstrated that cold resistance may be increased by decreasing the amount of water in the tissues by slight wilting. Wheat plants were dug up, wilted for two or three hours, and exposed to freezing temperatures. Turgid plants killed much worse than slightly wilted plants at a temperature of –2 to –3°C. for 20 to 30 minutes.

Chandler[20] compared the relative extent of killing by cold in turgid and wilted plants. He included in his experiments a large number of tender plants which are incapable of withstanding ice formation and which cannot be expected to show much response in the way of hardiness to any treatment. His experiments were made in summer, hence the killing at temperatures only slightly below freezing. Though Chandler concluded that on the whole, wilting does not increase cold resistance, yet the following table, taken from his data, indicates that under certain conditions, wilting may do so.

In the case of lettuce, it seems that the wilted plants were killed the worst by slight freezing, –2°C. At the lower temperatures, however, the percentage killed increases very rapidly in the turgid plants, and slowly in the wilted plants, so that the killing of turgid leaves considerably exceeds that of the wilted when the temperature of

EFFECT OF WILTING ON KILLING BY COLD, COMPILED FROM CHANDLER, p. 196.

Plant	Condition	Temperature			
		-2°C.	-3°C.	-4°C.	-4.5°C.
Lettuce	turgid wilted	12½% killed 47% killed		66.6% 55.5%	83% 62%
Red Clover	turgid wilted	17% killed 34% killed	100% 66.6%		
Rose Geranium	turgid wilted	97% killed 60%	100% 100%		
Red Cabbage	turgid wilted			65% 44%	

–4.5°C. is reached. The same thing is indicated in the case of red clover. Chandler remarks that brief wilting does not increase the total amount of material in the cell sap which might function in holding water in solution, yet it seems that the hardiness of the plants may be materially affected.

Wiegand[131] states that the greater the water content, the thicker the film of water on the surface of an imbibing substance, such as the plant cell, and the weaker the force by which the outer layers of this film are held, hence more easily withdrawn to form ice. Parker[97] has furnished some experimental data, which substantiates Wiegand's suggestion.

Kiesselbach and Ratcliff[52] in experiments with seed corn, found that death from freezing was directly proportional to the moisture content of the kernel and to the duration of exposure to cold. Seed corn maturing in the natural way was found to become cold-resistant progressively as the moisture content decreased. The following table taken from their data, illustrates the relation between moisture content and killing by cold as measured by the germination of the seed.

Kiesselbach and Ratcliff found that the temperature as which ice formation commences in the corn kernel depends very largely on the moisture content. Immature seed containing 60 to 80 percent moisture, froze just below 32°F., whereas in air-dry seed, containing 18 percent moisture, no ice formation could be detected at –10°F. Usually where ice formation took place in the seeds and they remained in the frozen condition 24 hours, the vitality was weakened or destroyed, but in some cases ice formation within the seed was not followed by

RELATIVE GERMINATION OF SEED CORN OF VARYING MOISTURE CONTENT AFTER EXPOSURE TO LOW TEMPERATURES. (After Kiesselbach & Ratcliff)

Temperature to which exposed Degrees F.	Percent moisture content of grain									
	10 to 15	15 to 20	20 to 25	25 to 30	30 to 35	35 to 40	40 to 45	45 to 50	50 to 55	60 to 65
32—28			100	85	75	71	69	—	33	0
24—20		100	96	77	67	13	12	12	6	0
16—12		100	88	34	12	0	0	0	0	0
8—4	100	98	47	7	0	0	0	0	0	0
0— -5	97	63	0	0	0	0	0	0	0	0

death. They show that air-dry seed are uninjured by low temperature, and that ice-formation does not take place therein.

The observations of Gorke, Schaffnit, Rivera, Hedlund, Shutt, Webber, Wiegand, Beach and Allen, West and Edlefsen, Batchelor and Reed and Johnson, indicate that individual plants, species or varieties having a low moisture content are usually hardier to cold than those having a high moisture content. The work of Chandler, Carrick, Beach and Allen, Salmon and Fleming, and Kiesselbach and Ratcliff indicates that reducing the moisture content of a given plant or part of a plant increases its cold resistance. This, it seems, may be partly accounted for by Wiegand's hypothesis and Parker's recent work, in that the force with which water is held by plant cells increases with decreasing water content. Removal of some water by drying before freezing should increase the force with which the remaining moisture is held. In other words, if plant tissues become more cold resistant upon slight drying out, such increase in hardiness may be ascribed to the increased power of imbibition on the part of the plant's cells.

Relation of factors influencing water loss by the plant as a whole, to hardiness.—The foregoing discussion has shown the relation of some factors to the water-retaining power of plant tissue, as measured by the effects of low temperature. It is indicated that increasing the water-retaining power of the cell, either by increasing the concentration of its sap, or by increasing its power of imbibition, or both, results in greater resistance to low temperature because of the increased force of crystallization necessary to withdraw the required amount of water to cause death or bring about the changes which cause death. If the ability of the individual cell to retain some moisture when exposed to freezing is the significant point of differ-

ence between tender and hardy tissues, then the plant as a whole may show the same difference in water-retaining power and resistance to water loss, but this does not imply necessarily that hardiness and drought resistance go together. Salmon[108] remarks that some hardy grasses thrive best in damp localities. In drought-resistant species, the plant as a whole may be protected against water-loss by morphological differences in structure, such as special water storage tracts, few or small stomata, thick integument, bark, scales, xerophytic characters in general; yet the individual cell may possess little water-retaining power which would prevent the excessive withdrawal of water upon freezing.

While a low transpiration rate due to morphological modifications would undoubtedly be of great assistance to plants in withstanding injury from physiological drought, a low transpiration rate also may be associated with high water retaining power of the cells.

Beach and Allen[6] observed a loss of four to nine percent in weight of apple twigs during a single week in January with a minimum temperature of –15°F. They found that in general the hardiest varieties are most resistant to the loss of water.

Strausbaugh[117] found that coincident with the breaking of the rest period in semi-hardy varieties of the plum in midwinter, the moisture-retaining power of twigs and buds decreased rapidly, while in the hardy variety Assiniboine, which remained dormant until early spring, the water-retaining power remained constant. This is significant, since increased tenderness to cold, especially of the flower buds, follows the break of the winter rest.

Sinz[115] concluded as a result of experiments at the University of Göettingen that those varieties of winter wheat which seemed able to prevent rapid transpiration, were among those most highly resistant to cold.

Weaver and Morgensen[126] in Nebraska found that in winter the water losses of coniferous trees with their needles intact, are relatively no greater than are the losses from deciduous trees after leaf-fall. This indicates great water-retaining capacity in the foliage of conifers, most of which are very hardy.

Some writers have likened hardy to desert plants because of their xerophytic characters, by which water loss is reduced to a minimum. Thus Schimper[112] states that desert plants frequently have a strong resemblance in their structure and habit of growth to those of polar regions, as would be expected if resistance to cold depended on the reduction of water loss to a minimum. What Schimper probably

had in mind was the form of injury due to physiological drought, where above-ground plant tissues are killed by desiccation resulting from their inability to obtain water from a frozen soil or through a frozen stem.

Storber[118] states that "winter leaves" of herbs are quite xerophytic in structure, enabling them to survive the severe conditions to which they are exposed. He points out a fact that seems to have been hitherto overlooked—that the low water content and high osmotic concentration in hardy plants may insure to them more ready absorption of soil water. This would certainly be of great importance to plants in winter, in overcoming physiological drought, as well as increasing the resistance to the direct effects of freezing. Dachnowski[22] observed xerophytic developments in plants exposed to physiological drought conditions in bogs. Modifications were found enabling certain plants to survive in bogs in spite of slow water absorption due to toxicity of bog waters. The following are the chief modifications to which Dachnowski ascribes resistance to rapid water loss in leaves of bog plants.

1. Reduction in size of leaves.
2. Thick-walled epidermis.
3. Cuticle, wax, and hairs.
4. Mucilaginous and resinous bodies in leaves and roots.

Groom[36] stated that the function of mucilages and tannin in buds is to help hold the water in the young shoots. Chandler[20] found that the bud scales of the peach had no influence on the resistance of the embryonic tissue to low temperature, but that they served as protection against drying out by repeated freezing and thawing. Wiegand[130] recognized that loss of water from the plant might take place by evaporation from the ice masses in frozen tissues, and suggested that bark and bud scales serve as protection against such loss. As pointed out earlier in connection with the rate of thawing, protection against such loss of water would be most important in tissues exposed to repeated freezing and thawing, as buds undoubtedly are in winter.

In a number of recent experiments on the raspberry in Nebraska, Emerson* found that by coating the canes with paraffin, winter-injury could be prevented. He observed that untreated canes killed only to the snow-line. Emerson's results indicate that mechanical protection against loss of water by the plant as a whole,

*Emerson, R. A. Cornell University, Ithaca, New York, Personal correspondence with F. C. Bradford.

may prevent the form of winter injury due to local physiological drought, wherein parts of plants exposed to repeated freezing and thawing and consequently to loss of water which cannot be replaced because of frozen stem or frozen or dry soil, are eventually killed by the progressive desiccation of the tops. This type of cold injury is distinct from the direct effects of low temperature, yet some of the factors which increase the water-retaining power of the tissues in the latter case may also be of importance in enabling the plant to withstand the former.

Irmscher[49] attempted to correlate the cold resistance of certain peat mosses with their ability to withstand long drying out. He found that most species could stand a temperature as low as –20°C., but they were all killed at –30°C. He states that "no thoroughgoing parallel was found between cold resistance and ability to survive long slow drying." However, he found that any particular species could be made more resistant to frost by previous drying out. Mosses growing in a dry location were found more hardy than the same species in moister places. Irmscher attributed to a "regenerative cell-complex" the means by which these mosses were enabled to survive both extreme cold and extreme drying. A higher osmotic concentration and greater cold resistance was observed in species of moss growing at low temperature.

STATEMENT OF PROBLEM.

The work of the earlier investigators shows that freezing to death of plant tissue is associated with water-withdrawal from the cells—the actual death process being due to (a) the direct effect of water subtraction on the protoplast, or (b) precipitation of proteins because of the increased acidity, or (c) precipitation of proteins due to increased salt concentration, or perhaps to other processes which have not as yet received attention.

Regardless of the particular theory which may account for the ultimate killing of plant tissue by cold, the consideration that the primary factor is water-withdrawal logically suggests the following questions. In general, would not cold resistance be proportional to the water-retaining capacity of the plant cells? Since the force of imbibition increases with decreasing moisture content and since also cold resistance in plants increases with decreasing moisture content, does not cold resistance depend largely on the imbibitional force with which the cells retain moisture? Do hardy plant cells actually retain more moisture when exposed to freezing than cells of tender

plants? Do tender plants exposed to hardening treatments acquire an increased cell-water-retaining power, and if so, is this the main factor concerned in their increased cold resistance? Also, how is this increased water-retaining power acquired and what changes in the living plant are concerned therein? In order to answer these questions, the following experimental work has been undertaken.

EXPERIMENTAL WORK.

Materials used.—Most of the experiments were performed with the cabbage, as a representative of a type of plant which is capable of being hardened so as to withstand considerable ice formation within the leaves. Leaf lettuce, head lettuce, kale, cauliflower and celery were used to some extent. These also are plants capable of being hardened so that they can be frozen stiff without injury.

The tomato was used as the principal representative of a type of plant which cannot be hardened so as to withstand ice-formation, but which is capable of hardening to the extent that the freezing point is lowered slightly. Other plants used of this type were peppers, eggplant and sweet potatoes.

In each series of experiments plants of the same variety and age were used.

Methods of hardening.—*Series E.*—The plants were kept in a warm greenhouse until nearly large enough for transplanting to the garden. The plants to be hardened were then removed to an open coldframe where they were exposed to temperatures near freezing during the night and to full sunlight during the day. This method of hardening was followed both in early spring and in late fall. Samples were gathered for analysis usually at intervals of 5, 10 and 20 days after the beginning of the hardening treatment, as well as from some of the original lot of plants which had been kept in the greenhouse under favorable growing conditions. The soil moisture supply was kept as nearly as possible the same for the plants in the greenhouse and those being hardened in the frames, so that temperature would be the principal limiting factor in their development.

Series A.—The soil moisture for plants grown in a warm greenhouse was varied. As soon as the seedlings were well established after transplanting from the seed flat, a number of potted plants of uniform size were selected and divided into lots which were given

different treatment only in so far as water supply was concerned. One lot, A1, was given liberal moisture—these plants were kept in rapidly growing condition and were always the tenderest plants in the experiments. Another lot, A2, was given moderate moisture, so that the plants grew at a moderate rate. Another lot, A3, was given just enough water to keep the plants growing slowly. They frequently wilted somewhat in the middle of warm, bright days. This lot usually showed nearly the same degree of hardiness as those plants that had received the maximum degree of hardening in the cold-frame. A fourth lot, A4, was included in some of the experiments, these plants being watered liberally at first, then water was partially withheld for a week or ten days before samples were taken.

Series B and C.—Plants were grown under uniform conditions in the greenhouse, in soils of different composition made up by mixing different proportions of sand and compost. Few data are reported on this series because it was found difficult to maintain uniform moisture conditions in soils of such diverse texture. Also other factors, such as degree of root binding, were likely to become limiting before excess or deficiency of nutrients could exert much effect. However, it was definitely shown that growing plants in poor soils would increase their cold resistance, other conditions being the same. Such plants were smaller and grew more slowly than the more tender plants in the better soils. This series of experiments might have been more successful if the plants had been grown in a uniform soil-medium to which varying quantities of nutrient solution were added.

Series H.—The treatment consisted of severely pruning the roots by running a knife close to the stem on one or both sides of the plant. This treatment checked the growth of the plants quite materially for a short time and increased the cold-resistance somewhat.

Series F.—A quite effective method of hardening was watering with M/10 solutions of various salts. The plants were grown under uniform conditions in a warm greenhouse and the test lots were watered with the various salt solutions whenever the soil became rather dry or whenever the plants wilted badly. In some cases, as under high transpiration conditions, the wilting point was reached while the moisture content of the soil was high. It is not altogether clear whether the hardiness resulting from these salt applications was due to their specific action, to a condition of mild physiological

drought, or to the toxicity of such concentrated solutions to the roots. This will be discussed in more detail later.

EFFECT OF HARDENING TREATMENTS ON PLANTS.

External appearance.—*Cabbage.*—Tender (wet-grown) greenhouse plants were usually about twice as large as those hardened by withholding of water, as shown by the relative green weights of A1 and A3 in Table 2. Plants hardened by withholding moisture were usually darker green, covered with heavy waxy bloom, with slight pink tints in the stem and petioles, but not as heavily pigmented as the coldframe hardened plants. The leaves were tough and leathery, in contrast to the brittle, crisp texture of tender plants.

Cabbage plants hardened by exposure in coldframe were smaller and stockier than unhardened greenhouse plants and nearly always showed more or less pink pigment (probably anthocyanin) in the stems, petioles and leaf veins. Coldframe hardened plants were tough and leathery in texture. In most of the experiments the maximum degree of hardening by this method enabled cabbage to withstand a temperature of –5°C. to –6°C. for at least one hour, whereas non-hardened plants would be killed between –3°C. and –4°C. In a few experiments hardened cabbage withstood temperatures as low as –8°C. to –10°C. over night.

The development of pink color, especially in the stems and petioles, was conspicuous in all hardened plants. According to Knudson[55] the "work of Ewart, Overton, Wheldale and others indicates a close relationship between the sugar content of the plant and pigment production." Throughout Knudson's experiments on the effect of carbohydrates on green plants, a tendency to anthocyanin production was observed, plants fed on glucose and maltose (M/20 solutions) showing heavy coloration, which disappeared within a week when they were placed in diffuse light. These results are of special interest in connection with the large sugar content found in hardened plants, discussed later.

Nicholas[91] was of the opinion that "the production (in leaves) of anthocyanin is correlated with the formation of organic acids. The connection known to exist between oxidation and pigmentation inheres in the production of these acids, accompanied by the formation of the red pigment."

The conspicuous development of the waxy bloom on cabbage plants has been considered by Harvey[42] of some importance in relation to cold resistance in that it may permit the undercooling of the

leaf several degrees below the freezing point. He suggests that it prevents the "inoculation" of the moisture in the leaf by droplets of water freezing on the surface.

Cabbage plants hardened by other methods showed much the same changes as did those in the series mentioned above. In all cases hardiness was in direct proportion to the external changes noted. Wherever the growth of the plant was materially checked, even for a few days, hardiness was increased in proportion to the checking.

Cauliflower and kale showed about the same changes on hardening as cabbage.

Leaf lettuce. Both small potted plants and large plants approaching maturity in the greenhouse and coldframe were used. The leaves become tougher, thicker and of more leathery texture upon hardening. Pigmentation was not conspicuous. When hardened by drying, the crinkling of the leaves was more pronounced and the color deeper green.

Tomato. Leaves of hardened plants became very dark green with much pigmentation on the under side, were much smaller, tended to curl on the midrib; the stems and petioles became very heavily pigmented, tough and woody in texture. Hardening tomato plants in the greenhouse by any of the methods of checking growth had about the same effect on external appearance. The same was true of the coldframe-hardened plants, except that when hardening was long-continued at low temperature, the lower leaves turned yellow and fell, until the plant was nearly defoliated. This is probably similar to the form of killing by temperatures above the freezing point noticed by Molisch and attributed by him to the inhibition of metabolism by the low temperatures.

Morphological difference in hardened plants.—Schaffnit[110] was unable to find any structural differences in varieties of wheat varying in degree of cold resistance. Salmon and Fleming[109] could find no difference in cell structure in hardy and tender varieties of cereals. On the other hand, Briggs[16] found that the cells were somewhat smaller in the pistils of hardy varieties of peaches. Walster[124] observed that in barley grown at 15°C., there was greater lignification of the xylem bundles than in plants grown at 20°C. This would make the plants grown at the lower temperature stiffer and stronger.

To determine whether the hardening process affects the size of the cells in vegetable plants, sections were made of hardened and

not hardened cabbage and tomato leaves and the palisade cells measured. Portions of young leaves which had made most of their growth during the process of hardening were used in each case. Hence the differences in the cells here reported do not represent an "acquired" condition, but differences in development between plants under favorable growing conditions and those subjected to hardening. Portions were taken from corresponding locations on leaves of about the same size, killed and fixed in the usual way. Transverse sections were made with the rotary microtone, mounted, stained and measured.

In the tender tomato leaf numerous large air spaces were observed, while in hardened leaves the cells were more compactly arranged and filled with starch grains. Starch grains were less plentiful in hardened cabbage leaves, but the compactness of the cellular arrangement was marked. Table 1 gives the measurements in two dimensions of the palisade cells and the cross-section area computed therefrom. These data are the averages obtained from measurements of several different sections.

TABLE 1.—MEASUREMENTS OF LEAF PALISADE CELLS IN PLANTS HARDENED AND NOT HARDENED.

	Thickness of whole leaf	Thickness of palisade	Thickness of parenchyma	Width of cells	Length of cells	Area, sq. μ.
Cabbage						
Not hardened	291μ	134.5μ	106.3μ	19.1μ	36.3μ	694.0
Hardened by drying in g. h.	269	127.9	106.3	19.4	27.8	538.8
Not hardened	274	136.2	102.1	20.9	36.9	772.0
Hardened in coldframe	312	168.6	118.0	19.9	31.1	619.5
Tomato						
Not hardened	196.6	76.2	76.2	21.0	57.5	1201.5
Hardened	133.7	55.6	68.0	14.1	44.8	630.1

Judging from the data presented in Table 1, hardened plants are characterized by somewhat smaller and more compact palisade cells than are non-hardened leaves of the same sort. In tomato, leaves from plants given hardening treatments are considerably thinner than tender leaves, however, cabbage leaves hardened in coldframe gained in thickness.

Effect of hardening treatments on rate of growth.—The growth of plants subjected to any of the hardening treatments was checked in proportion to the intensity of the treatment. Data are presented in Table 2, on samples gathered from lots of the same age, grown

under otherwise uniform conditions, except for the various hardening treatments. With the average green weight of the plants as the criterion, it is evident that hardened plants are much smaller, indicating the extent to which their growth had been checked. Thus, in the series gathered March 12, 1920, wet-grown greenhouse cabbage plants (tender) averaged 23.1 grams, plants hardened by partial withholding of moisture averaged 6.8 grams and plants hardened in coldframes three weeks averaged 7.67 grams. The differences in dry weight are not so great, since the smaller and hardier plants possessed a larger percentage of dry matter.

In the tomato, the rate of growth could be roughly measured by the increase in height from week to week. Accordingly a number in each of the lots subjected to the various treatments were measured each week. The retardation of growth, when any of the hardening treatments became operative, is shown in figure 1.

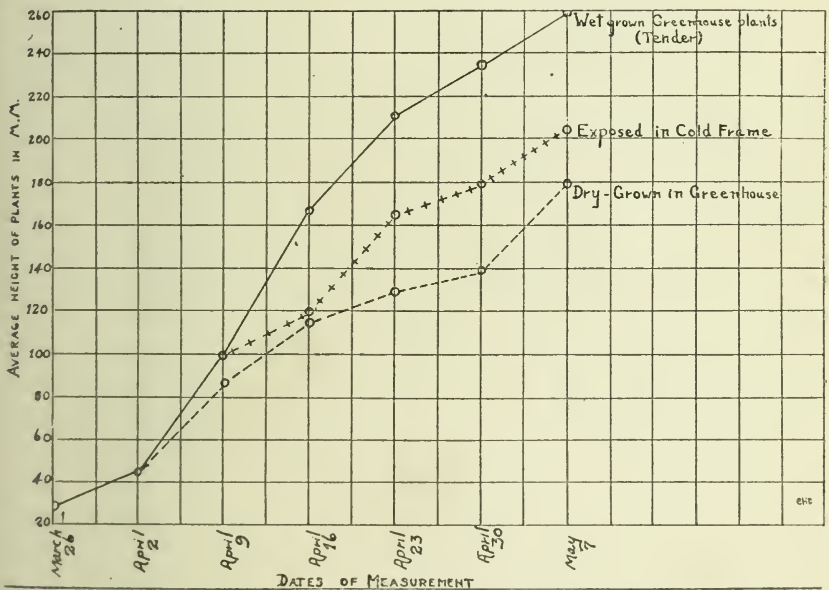

Fig. 1.—Rate of growth of tomato plants under various conditions.

Effect of hardening treatments on percentage of dry matter.—The data given under percent of dry matter in Table 2 indicate considerable increase of dry matter in all of the experimental lots of plants exposed to hardening treatments. Conversely, the water content decreased in hardened plants, roughly in proportion to the extent to which their growth was checked by the hardening treatment.

The possible significance of decreased water content in relation to the water-retaining power of the cell when exposed to water-loss by freezing has already been indicated by Wiegand and more recently by the work of Chandler, Salmon and Fleming, Carrick and indirectly by Parker. It may be repeated here that decreased water content would be associated with increased force of imbibition, and with increased concentration of the cell sap, which forces tend to retain water in the cell during freezing. It is realized that the *total loss* in weight upon drying of leafy tissue does not truly represent the actual water content of the plant, but the difference is probably so small that this loss is taken as the moisture content throughout these experiments.

Effect of hardening treatment on depression of freezing point.— In several experiments, the freezing point depression of the expressed sap of leaves of hardened and non-hardened plants was determined with the usual Beckman's apparatus. Potted plants from each experimental lot were brought into the laboratory to insure having fresh tissue for each determination. All of the leaves were taken from two or three plants and ground. The sap was then squeezed from the macerated pulp and duplicate or triplicate freezing point determinations were made at once. The data given in the column "Depression of the Freezing Point" in Table 2 show that the depression was somewhat greater in the hardened plants, indicating greater osmotic concentration of their sap. Similar data have been obtained by Chandler and by Harvey, working on the same sort of material, hence it was not deemed worth while to make a larger number of these determinations. The differences found here in freezing point depression are somewhat greater than those obtained by Chandler[20] and much greater than those reported by Harvey[42] for hardened and not hardened cabbage. This is due perhaps to the extremes in the treatments used in these experiments. Heavy watering made Series A1 somewhat more tender than ordinary non-hardened plants and Series A3 attained maximum hardiness through the application of the minimum amount of water to keep the plants from wilting.

It may be pointed out that the increased sap concentration in hardened plants is due probably to the combined effect of the following factors: (1) Decreased total moisture content. (See Table 2). (2) Increase in the amount of sap solutes. Numerous investigators have found an increase of soluble sugars in plants exposed to low

TABLE 2.—EFFECT OF HARDENING TREATMENTS ON SIZE OF VEGETABLE PLANTS, PER CENT OF DRY MATTER, DEPRESSION OF THE SAP FREEZING POINT, AND RESISTANCE TO COLD.

Plant	Series No.	Treatment	Date samples taken	Average green wt. plants	Average dry wt. plants	% of dry matter	Depression of freezing point	Relative Hardiness to Cold
Cabbage	A1	Optimum moisture, greenhouse	3/20/19 11/20/19 3/12/20	9.780 7.740 23.100	0.846 0.668 1.855	8.65 8.6 8.2	0.965°C. 0.785°C. 0.753	Killed at –4°C. in 1 hour Injured at –3° in 2 hours.
	A2	Medium moisture, greenhouse	3/20/19 3/12/20	8.240 10.05	0.837 1.132	10.17 11.30	1.048 1.115	Slightly injured at –4° in 2 hours. Uninjured at –3°C. in 2 hours
	A3	Minimum moisture, greenhouse	3/20/19 11/20/19 3/12/20	6.228 5.04 6.48	0.577 0.550 0.830	9.22 10.90 12.80	1.200 1.083 1.248	Not injured at –4°C. for 2½ hours. Not injured at –3°C. in 2 hours Not injured at –5°C. in 1 hour
	A4	Grown wet at first, then partially wilted for 2 weeks	3/12/20	12.20	1.311	10.76		Uninjured at –3°C. in 2 hours
	E4	Greenhouse plants not hardened	3/12/20 4/5/20	16.68 20.90	1.77 1.956	10.52 9.38	 1.043	Killed at –4°C. in 2 hours
	E3	Plants hardened in coldframe 1 week	3/21/19 11/20/19 3/12/20	7.787 5.270 13.63	0.928 0.602 1.680	11.90 11.71 12.31	0.963 0.963 1.132	{ Uninjured at –4°C. for 1 hour { Slightly injured at –4°C. 2½ hours Slightly injured at –6°C. in 2 hours
	E2	In coldframe 2 weeks	3/20/19 3/12/20	7.925 17.430	0.894 2.250	11.28 12.91	 1.109	Slightly injured at –6°C. in 2 hours
	E1	In coldframe 3 weeks	3/20/19 3/12/20	7.300 7.670	0.966 1.016	13.24 13.27	 1.157	Slightly injured at –6°C. in 2 hours
	D1	Grown in coldframe	11/20/19	1.195	0.155	12.55	1.200	{ Not injured at –4°C. in 2½ hours { Slightly injured at –4°C. for 1 hr.
	G2	Full light, greenhouse	3/20/19	6.487	0.753	11.60		Not injured at –2°C. for 1 hour
	G3	Light shade, greenhouse	3/20/19	6.580	0.627	9.52		Slightly injured at –2°C. for 1 hr.
	G4	Medium shade, greenhouse	3/20/19	1.654	0.107	6.43		Killed at –2°C. for 1 hour

TABLE 2.—(Continued).

Plant	Series No.	Treatment	Date samples taken	Average green wt. plants	Average dry wt. plants	% of dry matter	Depression of freezing point	
Cabbage	G5	Heavy shade. greenhouse	3/20/19	0.642	0.035	5.46		Killed at –2°C. for 1 hour
	H1	Greenhouse plants severely root pruned	4/5/20	5.58	0.72	12.90		
	H3	Greenhouse plants moderately root bound, not pruned	4/5/20	7.47	0.860	11.50		
	F	Compost soils and tap water	3/30/21	8.12	0.581	7.16		Not injured at –3° in 30 minutes Killed at –6°C. in 30 minutes
		Compost plus $NaNO_3$ M/10	3/30/21	4.63	0.431	9.31		Slightly injured at –6°C. in 30 min.
		Compost plus M/10 KCl	3/30/21	5.38	0.505	9.40		Not injured at –6°C. in 30 minutes
		Compost plus M/10 NaCl	3/30/21	4.76	0.455	9.57		Not injured at –6°C. in 30 minutes
		Compost soil plus manure, plus M/10 KCl	3/30/21	6.18	0.631	10.2		Not injured at –6°C. in 30 minutes
		Compost soil plus M/10 NaCl	3/30/21	6.53	0.624	9.55		Not injured at –6°C. in 30 minutes
		Sand and tap water	3/30/21	3.55	0.967	6.78		Slightly injured at –3°C. in 30 min. Killed at –6° in 30 minutes
		Sand and M/10 $NaNO_3$	3/30/21	8.58	0.560	6.52		Not injured at –3°C. in 30 minutes Killed at –6° in 30 minutes
		Sand plus M/10 KcL	3/30/21	8.32	0.523	6.29		Killed at –6° in 30 minutes
		Sand plus M/10 NaCl	3/30/21	8.56	0.546	6.37		Killed at –6° in 30 minutes

TABLE 2.—(Continued).

Plant	Series No.	Treatment	Date samples taken	Average green wt. plants	Average dry wt. plants	% of dry matter	Depression of freezing point	
Tomato	A1	Optimum moisture, greenhouse plants (leaves only)	5/3/19	36.660	4.175	11.40		
			9/21/19	15.083	1.252	8.29		
			12/11/19	23.90	2.016	8.44	0.820°C.	Killed at −2°C. in 1 hour
			5/4/20	49.20	4.05	8.24	0.815	
			4/30/21	12.96	1.262	9.73		
	A2	Medium moisture, greenhouse plants (leaves only)	5/3/19	7.811	0.927	11.86		
			9/21/19	15.592	1.640	10.52		
			5/4/20	24.80	3.050	12.28	1.450	Severely injured at −2°C. in 2 hrs.
			4/30/21	8.85	1.110	12.57		
	A3	Minimum moisture, greenhouse plants (leaves only)	5/3/19	2.427	0.399	16.45		
			9/21/19	8.641	0.949	11.00		
			12/11/19	7.320	1.100	15.4	1.370	Killed in 2 hours
			5/4/20	11.100	1.510	13.6	1.588	
			4/30/21	4.83	0.592	12.28		
	A4	Water partially withheld for 2 weeks	5/4/20	30.90	3.15	10.2	1.533	
	B6	Grown in ¾ loam, ¼ manure, in greenhouse	5/3/19	32.546	3.878	11.90		
			12/11/19	46.660	3.600	7.72	0.950	Killed at −2°C. in 1 hour
	B4	Grown in garden loam soil	5/3/19	10.149	1.408	13.98		Severely injured at −2°C. in 1 hour
			12/11/19	10.330	1.000	9.72	1.018	
	B2	Grown in ½ loam, ½ sand	5/3/19	2.448	0.379	15.50		Uninjured at -2°C. for 1 hour
			12/11/19	7.19	0.771	10.71	1.180	but killed in 2 hours
	B1	Grown in ¼ loam, ¾ sand	5/3/19	2.095	0.354	16.90	1.080	Slightly injured at −2°C. for 1 hour
			12/11/19	8.120	0.950	11.55		
	E4	Greenhouse plants not hardened	5/3/19	30.715	3.986	12.95		Killed at −1½°C. in 1 hour
			5/4/20	30.40	2.88	9.46	0.725	
	E3	Hardened in cold-frame for 7 days (leaves only)	5/4/20	27.0	3.15	11.67	0.784	Injured at −2°C. in 1 hour
			4/30/21	7.61	0.920	12.05		

TABLE 2.—(Continued).

Plant	Series No.	Treatment	Date samples taken	Average green wt. plants	Average dry wt. plants	% of dry matter	Depression of freezing point	
Tomato	E2	Hardened in coldframe 14 days (leaves only)	5/3/19 5/4/20 4/30/21	14.482 14.72 5.54	2.037 1.590 0.736	14.0 10.80 13.23	0.792°C.	Uninjured at –2°C. in 1 hour
	E1	Hardened in coldframe 21 days (leaves only)	5/3/19 5/4/20 4/30/21	14.326 14.50 6.00	1.963 1.440 0.850	13.7 9.93 14.17		Uninjured at –2°C. in 1 hour
Leaf Lettuce	A1	Optimum moisture, greenhouse plants	10/31/19 10/5/20	2.229 24.66	0.124 1.228	5.52 4.98		Killed at –3°C. in 1½ hours
	A3	Minimum moisture, greenhouse plants	10/31/19 10/5/20	1.290 2.47	0.084 0.231	6.56 9.36		Uninjured at –3°C. in 1½ hours Uninjured at –4°C. in 1½ hours
	A4	Minimum moisture, for 2 weeks, greenhouse	10/5/20	6.18	0.519	8.44		Slightly injured at –4°C. in 1½ hrs.
	B6	Rich compost soil, greenhouse	10/31/19	4.487	0.199	5.32		Killed at –3°C. in 3½ hours
	B2	Sandy soil, greenhouse	10/31/19	2.883	0.148	5.13		Slightly injured at –3°C. in 3½ hrs.
	E1	Medium moisture in warm greenhouse	3/24/20	2.00	0.157	7.85		Killed at –4°C. in 2 hours
	E2	Hardened in coldframe for 2 weeks	3/24/20 10/31/19	1.64 1.367	0.173 0.122	10.50 8.80		Uninjured at –3°C. in 3½ hours
	X1	Greenhouse plants nearly mature	11/29/19			3.98		Very tender
	X2	Mature plants in coldframe	11/29/19			7.02		Had been exposed to –5°C. several times with little injury
Head Lettuce		Head lettuce hardened in coldframe 10 days	3/24/20	2.67	0.296	11.13		Uninjured at –4°C. for 2½ hours
Cauliflower		Greenhouse plants not hardened	3/24/20	7.73	0.920	11.9		Killed at –4°C. for 2 hours
		Coldframe hardened	3/24/20	5.42	0.727	13.4		Uninjured at –4°C. for 2 hours

temperature and, as shown later, there is an increased sugar content in hardened vegetable plants. (3) Increased amount of water held in the absorbed state by the cell colloids. Since this absorbed water is probably nearly pure, the sap solutes of hardened plants are held in solution by a smaller volume of water—hence the greater concentration.

Chandler[21] found that a large part of the depression of the freezing point in plant sap was due neither to sugars nor to electrolytes. Recent work by Parker[97] showed that finely divided material in suspension exerted considerable influence on the freezing point and that this depression increases rapidly with decreasing moisture content. Though Parker's work was done with soils and dried, finely ground inorganic colloids, it may be supposed that the organic colloidal particles of plant protoplasm have the same property of depressing the freezing point. Parker attributes the lowering of the freezing point by finely divided material to the force of "adhesion" by which films of the liquid are held on the surface of the solid material. The freezing point depression caused by the finely divided material decreases almost to zero in presence of high moisture content. He explains this by the suggestion that as the amount of liquid increases some of it becomes so far distant from the solid particles and is so weakly held that no depression of the freezing point occurs. This is very nearly the same as Wiegand's theory as to the holding of water in plant cells by "molecular capillarity." It may be that the increase in colloidally-held water alone would account for much of the depression of the freezing point in hardened plants. Therefore it may be said that the apparent increase in osmotic concentration of the sap in hardened plants is merely coincident with the state of being hardy, rather than a cause of it.

EFFECT OF HARDENING ON ICE FORMATION IN PLANTS.

Previous investigations on freezing of plant tissue have shown that water is drawn from the cells to form ice in the intercellular spaces. Some plants are killed once this occurs. Others are capable of withstanding some ice formation, but are killed at lower temperatures. Unhardened cabbage plants are killed by freezing at –3°C. to –4°C. The same plants after being subjected to a hardening treatment, may withstand a temperature of –5°C. to –6°C. or even a few degrees lower.

Müller-Thurgau[74] has shown that by no means all of the water freezes in plant tissue when exposed to temperatures well below

the freezing point. His method of measuring the amount of ice in frozen plant tissue was based on observing the cooling of water in which tissue frozen to a definite temperature was placed, calculating that 80 calories are required to melt one gram of ice. In this way he was able to show that the amount of ice in an apple increased as the degree of freezing increased. The following table is taken from his data on frozen apples:

at	-4.5°C.	percent	total	water	frozen = 63.8
at	-7.3	percent	total	water	frozen = 68.2
at	-8.0	percent	total	water	frozen = 72.4
at	-13.0	percent	total	water	frozen = 74.4
at	-14.8	percent	total	water	frozen = 77.4
at	-15.2	percent	total	water	frozen = 79.3

It appears from these data that the amount of water frozen at each successive fall in temperature decreases fairly regularly until –13°C. is reached, but below that temperature the rate of ice formation increases somewhat. The latter temperatures are far below the killing point for apples, which may affect the results, and Müller-Thurgau's technique may be open to some experimental error.

Müller-Thurgau also made some interesting determinations of the time-rate of ice formation. Kohl-rabi leaves exposed to a temperature gradually declining from –5°C. to –8.25°C. froze at the

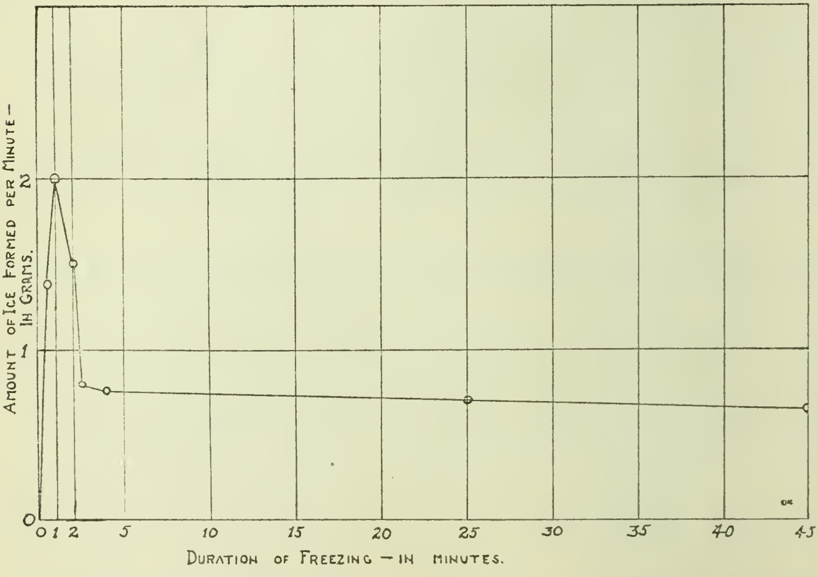

Fig. 2.—Relation of time to rate of ice formation in 100 grams kohl-rabi leaves (arranged from Müller-Thurgau's data).

end of 13 minutes, when the temperature of the leaves was only –4.3°C. and that of the surrounding air was –7.3°C. In the first half minute of freezing 0.69 grams of ice formed in 100 grams of leaves. In the next minute, 2.0 grams, the following two minutes, 1.5 grams per minute, and the next minute, 0.8 grams froze. Thereafter the amount of ice formed per minute gradually decreased until, at the end of one hour of freezing, 41.32 grams of ice had formed in 100 grams of leaves, probably a little over 50 per cent of the total water content. This experiment is illuminating as to the relation of the time factor to freezing of plants. It has been observed that in plants, such as kohl-rabi, which can withstand some ice formation, injury at a temperature near the death point is proportional to the duration of exposure. This fact has been observed frequently in experiments here and Harvey[42] presents in his paper an excellent series of photographs illustrating the same thing. Figure 2 plotted from Müller-Thurgau's data, illustrates graphically the rate of ice formation. We may regard the progressive increase in total amount of ice and the decrease in amount frozen per minute as being due to the balanced action of the force of crystallization and the water-retaining power of the cells, the rate of ice-formation approaching zero as a limit.

Foote and Saxton[28] used the dilatometer in experiments on the freezing of inorganic colloids and were able to show that in such materials water existed in three forms, viz., free water, capillary absorbed water and water of chemical combination. Recently, Bouyoucos[10] and McCool and Millar have made use of the dilatometer to measure the amount of water freezing in soils, in plants and in seeds. McCool and Millar in their latest report, state that the amount of water freezing in plants at –1.5°C. decreased as the concentration of the sap increased (as measured by the freezing point method). At –4°C. the amount of water freezing was considerably more than at –1.5°C. and its correlation with the freezing point of the sap almost disappeared. The following figures rearranged from their report illustrate this:

Crop-plant	Date	Freezing point depression	Amount of water freezing in 5 grams of leaves. At -1.5°C.	At -4°C.
Wheat	Nov. 14	1.107°C.	0.40cc.	2.65cc.
Rye	May 17	1.030	.86	2.40
Rye	Nov. 24	.928	.90	2.50
Sweet clover	Nov. 24	.906	1.22	2.82
Red clover	May 15	.780	1.70	2.70
Corn	June 10	.578	2.10	2.90

Unfortunately they did not express their results as percentages of the total moisture content in each of the different plant tissues, hence it is impossible to draw very definite conclusions. Also nothing is stated as to the source of the material, whether greenhouse or field grown. One interesting point to be noted here is that wheat and rye, which one would expect to be more cold-resistant than corn or clover, show a smaller amount of water frozen at –1.5°C. and somewhat less at –4°C. It is rather surprising that such decided variation in sap density made so little difference in the amount of water freezing at –4°C.

In another series of experiments with corn and barley McCool and Millar[80] showed that varying the soil moisture content affected the water relations in the plants. Freezing point depression and the percentage of moisture in the tops decreased slightly in plants grown with 15.53 percent soil moisture, as compared to those grown with 23.29 percent soil moisture. The amount of water freezing at –2.5°C. was decreased somewhat, and the amount freezing at –4.5°C. was decreased considerably in plants grown on the soils of lower moisture content.

Hibbard and Harrington[45] found that the freezing point of the sap of roots and tops of corn plants fell regularly as the moisture content of the soil in which the plants were grown was decreased. The following data from their work illustrate the relation of soil moisture to freezing point depression of sap.

Percent moisture in soil	Freezing point depression of tops	of roots
31	1.835°C.	.492°C.
23	1.920	.600
16	2.027	.647
13	2.120	.942
11	2.204	.995

McCool and Millar[80] studied the effects of varying the concentration of the soil solution, when the moisture content was kept constant. They found a progressive increase in the freezing point depression of the tops and roots of plants grown in the greater concentrations, but the amounts of freezable water showed little variation. Earlier experiments by the same authors[78] showed that the freezing point depression of both tops and roots varied in the same direction as the concentration of the soil solution in which the plants were grown but not in proportion to it. They also studied the effect of varying the soil moisture content, keeping the concentration of the soil solution constant. Unfortunately, in their experiment

the plants on the high moisture soils took up a larger quantity of the nutrient salts so that the concentration of the soil solution soon became less than in the low moisture soils. Therefore, it remains undetermined whether the effects of wet and of dry soils on freezing point depression and amount of freezable water in plants grown thereon are due to the variation in the water supply, or to variation in concentration of the soil which is involved, or to both.

Method of measuring amount of water freezing in plant tissues. Though Müller-Thurgau was able to obtain considerable data on this subject by measuring the latent heat of ice in frozen tissues, his method is laborious and perhaps open to some experimental error. The dilatometer method, as described by Bouyoucos[11], presents great advantages in its directness, simplicity, and accuracy for measurements at different degrees of freezing. The use of the dilatometer is based on the fact that one gram of water increases approximately one tenth of its volume upon freezing. It has been used in this work essentially as described by Bouyoucos, and by McCool and Millar.

A definite weight (4–6 grams) of fresh leaves, is placed in the bowl of the dilatometer, which is then filled with petroleum ether (boiling point 63°C.). The dilatometer is then stoppered with a rubber cork through which a thermometer is placed, so that the bulb is in contact with the leaf tissue and the scale convenient for reading. It was found at the beginning of this work that quicker and more accurate results can be obtained with plant tissues, by placing the loaded dilatometer in crushed ice for 15 to 20 minutes, to lower the temperature of the whole mass slowly and evenly to the neighborhood of 0°C. After this preliminary cooling, the dilatometer is plunged into an ice and salt bath, mixed in such proportions that the temperature is slightly below that which is desired in the dilatometer. Usually the temperature of the plant tissue in the dilatometer lags slightly above that of the freezing mixture. The dilatometer must be kept perfectly still after it is placed in the bath in order to secure uniform under-cooling of the plant tissue, but the freezing mixture can be gently stirred so as to keep all parts of the bath at uniform temperature.

At first the column of petroleum ether in the graduated side-arm of the dilatometer falls rapidly due to the contraction of the contents on cooling. It is usually necessary to add a little more ether to bring the column up to the point on the scale where it can

be read easily. When the thermometer indicates that the contents of the dilatometer have been desired temperature for several minutes, the position of the column in the side-arm is read, then solidification of the under cooled water in the plant tissue is caused by tapping the dilatometer against the sides of the bath. As solidification of the water takes place, the column rises in the side arm, slowly at first, then more rapidly and then quite slowly for several minutes. It usually takes 5 to 10 minutes to establish equilibrium, indicating that all the water is frozen which will freeze at that temperature. When the column of ether in the side arm becomes stationary, the reading is taken. The amount of expansion as a result of the freezing is the difference between the readings before and after freezing. In this work the side arm tube was graduated to 0.01 cc. and readings could be made to 0.005 cc. The expansion on freezing multiplied by 10 gives the number of cc. of ice formed. In some of the earlier experiments separate samples were used for moisture and dry matter determinations. Later it was found that these determinations could be made on the dilatometer sample after the freezing experiments had been performed. The water content of the tissues being known, the percentage of the total water frozen can be calculated by dividing the number of cc. of ice formed by the total water content of the sample.

Effect of temperature on amount of water freezing in hardened and non-hardened cabbage leaves.—Cabbage leaves were used in most of the experiments, since these were available in varying degrees of hardiness. It was found very difficult to secure rapid crystallization in hardened cabbage leaves at a temperature higher than –3°C., so that point was taken for the minimum reading. On the other hand, leaves could seldom be under cooled below –6°C. without ice formation, so that point was taken as the maximum limit of freezing in most of the experiments. Dilatometer determinations were made a number of times with each class of material under experiment. These determinations were distributed over a period of several months. The samples were taken at different times of day, but in each series samples were taken at the same time of all the different types of material which were being compared. Table 3 gives the results secured with leaves of non-hardened greenhouse cabbage plants thoroughly hardened in coldframe (9-12 days) and of plants hardened in the greenhouse by partial withholding of water for two weeks or more. Each figure represents an average of several determinations, the individual determinations sometimes varying as much

as 10 percent due to slight differences in the material and to the hour at which the samples were taken.

TABLE 3.—PERCENTAGE OF TOTAL MOISTURE IN CABBAGE LEAVES FROZEN AT DIFFERENT TEMPERATURES.

Previous treatment of plants	Percent of dry matter	Percent of total moisture freezing at			
		–3°C.	–4°C.	–5°C.	–6°C.
Wet-grown greenhouse plants, (tender)	10.29	49.9	75.2	82.1	84.2
Dry-grown greenhouse plants, (hardy)	12.7	27.2	48.9	62.6	71.0
Hardened in coldframe 9-14 days, (hardy)	14.67	29.8	49.6	58.7	64.3

Considerably more water froze in the tender plants than in the hardened at each temperature. The material used for the dry-grown hardy plant determinations perhaps was not quite so uniformly hardy in its nature as that of the two other types. The outstanding feature is the progressive increase in percentage of total moisture frozen as the temperature is lowered. This is brought out clearly in Figure 3 plotted from the data in Table 3. The increase becomes less and less for each degree of temperature lowering. Thus in the case of the tender cabbage, 26.3 percent more water freezes at –4°C. than at –3°C., 6.9 percent more freezes at –5°C. than

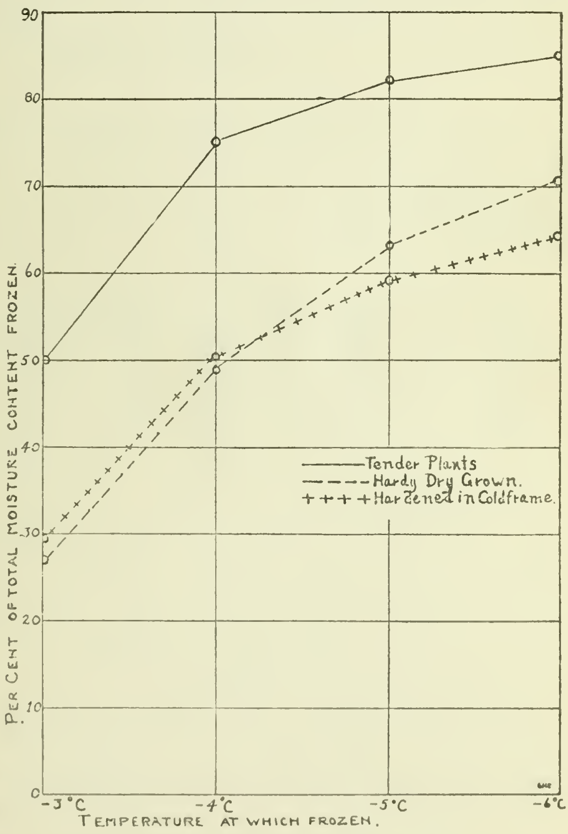

Fig. 3.—Relation of temperature to percent of total moisture freezing in tender and hardened cabbage leaves.

at –4°C. and 2.1 percent more freezes at –6°C. than at –5°C. In the coldframe hardened plants, 19.8 percent more water is frozen at –4°C. than at –3°C., 9.1 percent more at –5°C. than –4°C., and 5.6 percent more at –6°C. than at –5°C. Table 3 shows that the percentage of total moisture frozen at a given temperature is less in the hardened plants. Table 3A, constructed from the same data, on the basis of 100 grams fresh tissue, shows that the actual amount of water remaining unfrozen is greater also in the hardened leaves although there is a smaller total moisture content in such tissues than in tender leaves.

TABLE 3A.—AMOUNT OF WATER IN 100 GRAMS OF CABBAGE LEAVES REMAINING UNFROZEN AT DIFFERENT TEMPERATURES.

Treatment	Percent dry matter	Percent moisture	Grams water remaining unfrozen at			
			–3°C.	–4°C.	–5°C.	–6°C.
Wet-grown greenhouse plants, tender	10.29	89.71	34.9	22.3	16.1	14.3
Dry-grown greenhouse plants, hardy	12.70	87.30	63.5	44.6	32.6	25.3
Coldframe, hardened for 9-14 days	14.67	85.33	59.9	42.9	35.2	30.4

Since the percentage of the total moisture which freezes at each temperature is materially less in hardy than in tender plants, and since the actual amount of water remaining unfrozen is greater in the hardy than in the tender plants, we may safely assume that the cells of the hardened plants possess a greater power to retain water when exposed to freezing. Although the amount of water frozen increases with the lowering of the temperature, we may assume that whatever the nature of the water-retaining force, it is overcome in successively smaller increments by the force of crystallization as the temperature is lowered. The percentage of water remaining unfrozen in the hardened leaves is approximately a logarithmic function of the temperature.

The hardiest plants used in this experiment probably could have been killed by long exposure to –6°C. to –8°C. However, it may be predicted from the rate of increase in the amount of water frozen at the lower temperatures, that if in some way the water-retaining power of the cells in these plants was increased slightly, a much lower temperature could have been sustained. Maximow has shown that sections of cabbage leaves which were injured at –5.2°C. when

frozen in water, successfully withstood a temperature of –32°C. in 2–mol. sugar solution.

Changes in amount of freezable water during the hardening process.—Harvey[42] stated that cabbage plants kept at 3°C. for 24 hours showed slightly increased hardiness and at the end of five days a considerable degree of hardiness was developed. In the present experiments, absolutely controlled conditions were not available; however, it is generally considered that about two weeks' exposure of greenhouse-grown cabbage plants in the open coldframe during March will bring about maximum hardening. To study the relation of the amount of freezable water to the hardening process, lots of tender cabbage plants were removed from the greenhouse to the coldframe at intervals and dilatometer determinations made on the leaves of these plants which represented progressive degrees of hardening. The results are presented in Table 4.

TABLE 4.—AMOUNT OF WATER FREEZING AT -5°C. IN CABBAGE LEAVES HARDENED IN COLDFRAME FOR DIFFERENT LENGTHS OF TIME.

Treatment	Percent dry matter	Percent water	Percent total water frozen	In 100 grams of tissue	
				grams water frozen	grams water unfrozen
Not hardened	9.91	90.09	82.1	73.96	16.13
Hardened 2 days	13.20	86.80	75.3	65.32	21.48
Hardened 4 days	13.90	86.10	62.8	54.47	31.63
Hardened 9 days	14.00	86.00	58.7	50.48	35.62
Hardened 14 days ...	14.79	85.21	54.6	46.52	38.69
Hardened 16 days ...	18.7	81.3	51.0	41.46	39.84
Hardened 20 days ...	19.35	80.65	47.9	38.63	42.02

It appears that the percentage of the total water frozen at –5°C. decreases as the plant tissue increases in hardiness. At the same time the amount of total moisture in the plants decreases, accompanied by an increasing percentage of dry matter. The relation of degree of hardening to the percentage of freezable water and to dry matter content is shown graphically in Figure 4. The dates of decrease in percentage of water frozen and of increase in percentage of dry matter proceed quite rapidly the first four or five days the plants are exposed to hardening in the coldframe. After this, these changes proceed slowly for some days longer. On the whole, it seems that there is a close correlation between the degree of hardiness and the percentage of total water retained in the unfrozen condition. The actual amount of ice per gram of fresh leaf tissue also decreases

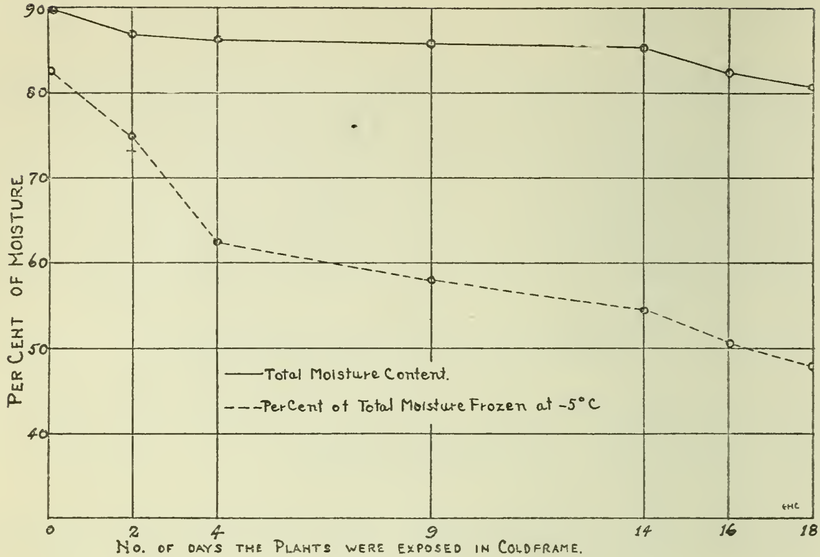

Fig. 4.—Relation of degree of hardiness to percentage of total moisture and percentage of water at -5°C. in cabbage leaves.

with the degree of hardening, while the actual amount of water remaining unfrozen increases as shown in Figure 5.

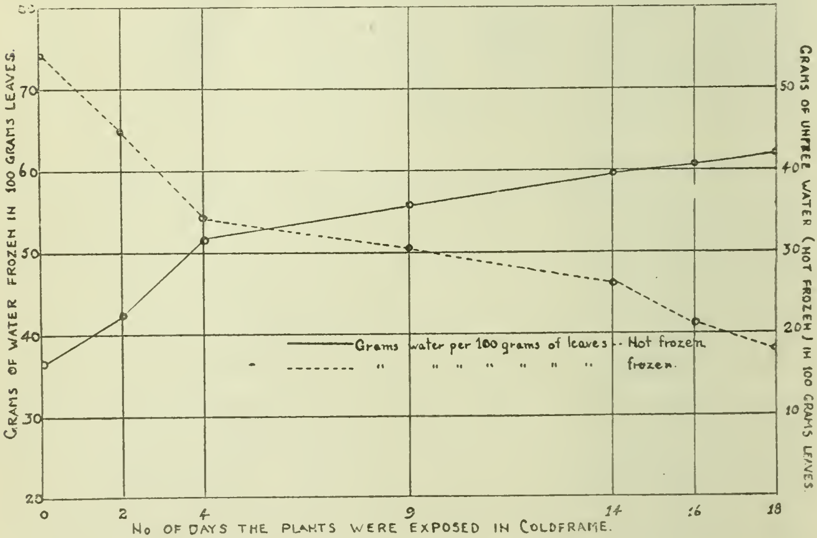

Fig. 5.—Relative amounts of water frozen and not frozen at -5°C., in 100 grams cabbage leaves of varying degrees of hardiness.

Influence of time of day on percentage of water frozen.—McCool and Millar[80] found that the time of day influenced both the depression of the freezing point and the amount of water frozen at a given temperature. Their experiments with various cereal plants showed that the freezing point depression of the leaves increases during the forenoon, declines slightly in the afternoon and almost reaches the early morning value by midnight. Over the same period the percentage of total moisture varied inversely with the depression of the freezing point, but to a much less degree. Shaded oat plants decreased steadily in sap density during the day, while exposed plants showed the usual increase at mid-day. The slight difference in water content of plants is held by these writers to be insufficient to explain fully the increased sap concentration at mid-day, hence it seems that the products of photosynthesis must play a part. Barley plants kept under bell jars in a saturated atmosphere, under conditions retarding transpiration but permitting photosynthesis, had 55 percent of the water in the tops and 62 percent of that in the roots frozen at –3°C. to –4°C. in the morning. At noon 43 percent of the water was frozen in the tops and 59 percent in the roots, at the same temperature.

It has been shown by Dixon[133] that illumination increased the osmotic concentration in leaves and this concentration gradually fell when light was cut off. Chandler[20] also found that plants shaded 24 hours had decreased concentration. According to Drabble and Drabble,[134] a greater concentration of cell sap occurs in plants subjected to factors favoring rapid loss of water by transpiration. Under these conditions the increased concentration of cell sap is probably very largely the result of, as well as the means of protection against, rapid loss of water from the leaves.

In the course of the experiments on the amount of water freezing in cabbage leaves of different degrees of hardiness, some data were obtained relative to the effect of the time of day on the amount of water freezing in leaves of the same hardiness. No attempt was made to provide specially controlled conditions; they were the same as those previously described for the various hardening treatments and were identical with those referred to in Table 2.

TABLE 5.—EFFECT OF TIME OF DAY ON AMOUNT OF WATER FROZEN IN CABBAGE LEAVES AT -5°C.

Material	Time	Percent moisture in plants	Percent water frozen at –5°C.
Wet-grown greenhouse plants (tender)	9 A. M.	90.43	82.4
	2 P. M.	90.22	78.2
	6 P. M.		85.9
Dry-grown greenhouse plants (hardy)	9 A. M.	86.60	55.8
	2 P. M.	86.39	47.1
Coldframe hardened plants	9 A. M.	87.87	61.9
	2 P. M.	84.12	55.5

It is seen that the amount of freezable water is somewhat greater in the morning than in early afternoon, but the differences are not as great as those found by McCool and Millar. The moisture content is also somewhat less in the afternoon indicating the possibility of a greater power of imbibition at that time. Probably the larger factor in causing the slight difference in amount of frozen water is the increased concentration of sugars formed by the photosynthetic activities of the leaf. Both the moisture content and the concentration of cell sap evidently have some influence on the amount of freezable water.

Effect of watering plants with salt solutions on amount of easily frozen water in the leaves.—A method used to harden vegetable plants was watering with salt solutions. Only one of these experiments will be discussed here. On February 15, seedling cabbage plants were potted in 3-inch clay pots, which were plunged in soil on a raised bench in the greenhouse. One series was potted in river sand, one in greenhouse compost soil and a third in compost plus rotten stable manure. Each series was divided into four plots and after the plants were well established one of each series was watered with: (1) tap water, (2) M/10 $NaNO_3$, (3) M/10 KCl, (4) M/10 NaCl. These applications were repeated every few days, when water appeared to be required. After the second application, the rate of growth in the different plots was evidently being affected. All of the salt solutions depressed growth but particularly in the series grown in compost and in the compost and manure mixture. Plants growing in the sand showed some of this stunting effect, but much later than in compost soils. A test made March 30 showed that the plants grown in the compost soils and stunted by the salt applications were much hardier than those receiving tap water and making normal growth. Little effect of the salts upon either the size or

hardiness of the plants grown in sand could be observed. Plants grown in the compost soils and watered with NaCl were exposed to –6°C. for 45 minutes without injury. Plants in compost soils watered with KCl and $NaNO_3$ were injured somewhat under the same conditions, and those receiving tap water were killed. Plants from all of the lots grown in sand were killed at –6°C., but when exposed to –3°C. to –4°C. for one hour, only those receiving water were much injured. The day following the freezing tests, dilatometer determinations were made on leaves of plants from some of the lots given different treatments, the results being shown in Table 6. Most of these figures represent only one determination. The samples were gathered about 1:30 P. M. on a bright sunny day, which may explain why the percentage of water frozen in some of these plants is a little less than that shown in Table 3 for tissues of approximately the same degree of hardiness.

TABLE 6.—AMOUNT OF WATER FREEZING AT -5°C. IN CABBAGE LEAVES FROM PLANTS WATERED WITH VARIOUS SALT SOLUTIONS.

Treatment of plants	Percent dry matter	Percent moisture	Percent total water frozen at –5°C.	Grams water frozen in 100 grams of leaves
In compost soil watered with tap water (medium tender)	10.86	89.14	61.2	54.55
In compost soil watered with M/10 $NaNO_3$ (hardy)	11.83	88.13	37.3	32.87
In compost soil watered with M/10 NaCl (hardy)	12.02	87.98	39.5	34.76
In compost and manure-watered with M/10 NaCl (very hardy)	14.03	85.97	27.2	23.29
In sand watered with tap water (very tender)	8.24	91.76	79.8	73.22
In sand watered with M/10 NaCl (medium tender)	11.01	88.99	59.4	52.86

The percentage of water frozen is much less in the stunted plants—those found most hardy to cold. The amount of water frozen is correlated with the observed degree of cold-resistance and the extent to which growth was checked. Here again the percentage of water frozen varies inversely with the percentage of dry matter. Unfortunately the freezing point depressions of the plants used in this experiment were not taken. However, we know from Chandler's work that the sap of plants watered with salt solutions has an increased osmotic concentration. Bartetzko[4] found that *Aspergillus*, *Penicillium* and other fungi grown in nutrient media of varying

concentrations increased their resistance to freezing in proportion to the increase in the osmotic strength of the medium.

The question arises as to how the application of salt solutions to soils in which plants are growing checks growth, increases cold resistance and reduces the amount of freezable water. The stunting might be due to: (a) The toxicity of the salt solution to the roots of the plants at the concentration used. However, since the salt solutions were not appreciably toxic to the plants grown in sand, it seems doubtful if the stunting and hardening of the cabbage plants in the compost soils can be attributed to this factor. (b) Absorption of the salts by the plants, causing a greater concentration of the sap, yet why should nutrient salts such as $NaNO_3$ cause a stunting of healthy plants? (c) Condition of physiological drought within the plant, at least at such times as the moisture content of the soil was low or the rate of transpiration very rapid. Such a condition might easily arise, in treating a succulent plant such as cabbage, with rather strong salt solutions. If the tops of the plants suffered from physiological drought a considerable part of the time because the roots were unable to absorb water rapidly from the more concentrated soil solution, then a condition would exist more or less similar to that in ordinary soils wherein plants have been hardened by partially withholding moisture. The fact that the lots grown in sand did not show nearly so much of the checking or stunting effect as those grown in the finer soils containing more organic matter lends strength to this idea. To see whether or not the observed results might be due to variations in the concentration of the soil solution this was determined in each lot at the end of the experiment. The method of Bouyoucos[13] was employed, taking 15 grams of air-dry soil and 10 cc. of distilled water, determining the freezing point depression with the Beckman thermometer, and calculating that the soil solution contained 100 parts of solute per million for each 0.004°C. of freezing point lowering. The results are presented in Table 7.

TABLE 7.—CONCENTRATION OF SOIL SOLUTIONS AFTER M/10 SALT SOLUTIONS WERE APPLIED FIVE TIMES.

Treatment	Sand		Compost		Compost and manure	
	Freezing point depression	p.p.m. in soil solution	Freezing point depression	p.p.m. in soil solution	Freezing point depression	p.p.m. in soil solution
Tap water ..	.005°C.	125	.045°C.	1125	.159°C.	3975
M/10 $NaNO_3$ ..	.020°C.	400	.277	6925		
M/10 KCl ..	.020°C.	400	.210	5200		
M/10 NaCl ..	.020°C.	400	.263	6576	.367	9175

The results set forth in Table 7 show that at the conclusion of the experiment, just after samples for the dilatometer determinations had been taken, the concentration of the soil solutions had increased very markedly in the compost soils to which the salts were applied, as compared to the check of the same sort of soil, but receiving tap water. However, in sand the soil solution was much less concentrated and there was no great increase in the concentration of the soil solutions where the salts were applied. Bouyoucos[13] has shown that

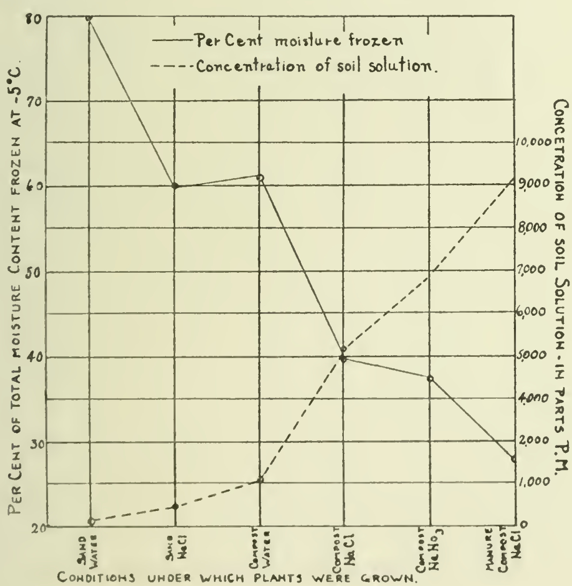

Fig. 6.—Relation of soil solution concentration to percent of water freezing at -5°C. in cabbage leaves.

soils containing much organic matter cause a large amount of practically pure water to become "unfree" by means of capillary adsorption. At a given moisture content therefore, the free solution in such soils would be more concentrated than in a sandy soil having little organic matter and large soil particles. Comparing the data in Tables 6 and 7 it is observed that the amount of water frozen in plants at –5°C. varies inversely to the concentration of the soil solution, but probably not in proportion to it. This point is illustrated by Figure 6.

To show to what extent the growth of plants in this experiment was affected by the salt applications in the three soil media used, the average green weights, average dry weights, and percentages of dry matter are given in Table 8, for the plants in each lot at the end of the experiment (one day after the freezing determinations were made).

TABLE 8.—AVERAGE GROWTH MADE BY CABBAGE PLANTS IN SOILS RECEIVING FIVE APPLICATIONS OF M/10 SALT SOLUTIONS.

Treatment	Sand			Sandy compost			Sandy compost and horse manure		
	Green wt.	Dry wt.	% dry matter	Green wt.	Dry wt.	% dry matter	Green wt.	dry wt.	% dry matter
Tap water ...	13.55	.967	6.78	8.12	.581	7.16			
M/10 $NaNO_3$.	8.58	.560	6.52	4.63	.431	9.31			
M/10 KCl ..	8.32	.523	6.29	5.38	.505	9.40	6.18	.631	10.22
M/10 NaCl ..	8.56	.546	6.37	4.76	.455	9.57	5.53	.624	9.55

It is seen from Table 8 that the plants in the sand made nearly twice as much growth as plants receiving corresponding treatment in the compost soils, using the average green weights as the indicator. It should be remembered that in this experiment a rather high soil moisture was maintained in order to prevent the lack of water from influencing the results; furthermore this experiment was ended before the lack of nutrient material in the sandy soils could become the main factor limiting their growth.

The indications point to the conclusion that applications of rather strong salt solutions raised the concentration of the soil solution to a point at which roots could take up water only slowly, and probably not at all when the total soil moisture content fell below a certain point. This developed a state of physiological drought in the tops due to the restricted water intake. Under these conditions, the leaves developed xerophytic characteristics to some extent, as indi-

cated by the greatly increased water-retaining power on the part of the cells. This is shown by the smaller amounts of water frozen in the leaves of such plants, and as is shown later, by the lower transpiration rate, and slower rate of drying in an oven. Another example of increased cold resistance apparently resulting from physiological drought was observed in the field in the spring of 1921. On March 31, the temperature fell to –8°C., and the following night to –6°C. Hardened cabbage plants set in the field 10 days previous, were very severely injured, but here and there thru the field small plants were observed after the freeze, the leaves of which were apparently uninjured. On examination, the stems of all such plants were found to be nearly severed by a "damping off" fungus. Evidently the stem injury by the fungus had caused physiological drought in the top of the plant, resulting in considerable increase in hardiness.

Relation of amount of freezable water to percentage of dry matter and freezing point depression in garden plants.—Three species of plants were used in these experiments, cauliflower representing a group possessing potential hardiness, and tomatoes and sweet potatoes representing plants lacking potential hardiness. Leaves were gathered during June from plants growing under ordinary conditions in the garden. The soil was fairly moist at this time and the plants were making good growth. A portion of each lot of leaves was used for the dilatometer determination, and another portion for determination of the freezing point depression. This latter was made, not on the expressed sap, as were the previous determinations herein reported, but directly on the triturated leaf tissue, according to the method of Bouyoucos and McCool.[14] The results are given for two sets of determinations in Table 9. In the last two columns of this table are given the relative amounts of frozen and unfrozen water, calculated on the basis of 100 grams of fresh leaf tissue.

The plants used in these experiments would probably have been killed by a brief exposure to –3°C., except the cauliflower, which might have withstood a somewhat lower temperature. It may be seen from Table 9 that the percentage of total water freezing in cauliflower at –5°C. is somewhat less than in tomato and sweet potato, while at –3°C. this difference is much greater in favor of the hardier cauliflower. The amount of water remaining unfrozen is correspondingly greater in cauliflower. It appears that allowing cauliflower leaves to stand in 8 percent sucrose over night has increased the percentage of dry matter and the freezing point depression and has decreased the amount of water freezing at –5°C. The

TABLE 9.—AMOUNT OF WATER FROZEN IN LEAVES OF GARDEN PLANTS.

Date	Plant	% dry matter	Freezing point depression	In 100 grams leaf tissue frozen at −5°C. % water frozen	grams water frozen	grams water unfrozen
June 8	Cauliflower (in 8% sucrose over night)	15.86	.780°C.	57.0	48.0	36.14
" "	Cauliflower (in water over night)	13.26	.413	77.4	67.1	19.64
" "	Tomato	11.73	.650	79.3	70.0	18.27
" "	Sweet Potato	17.5		83.0	69.4	13.1
				Frozen at −3°C.		
June 21	Cauliflower	17.7	1.300	28.3	23.3	59.0
" "	Tomato	13.5	.915	43.7	37.9	48.6
" "	Sweet Potato	14.84	.750	48.1	41.0	44.16

amount of water remaining unfrozen in the cauliflower leaves which had been in the sugar solution is nearly twice as much as in the check leaves kept in water. Since sucrose penetrates plant tissue quite slowly, the changes noted are probably not due to increased sugar content. However, the dry matter is 2.60 percent or nearly $\frac{1}{5}$ greater in the leaves placed in sugar solution. The 8 percent sucrose solution is approximately equivalent to 0.25 molecular concentration. Under these conditions, water may be withdrawn from the leaf, thereby decreasing the moisture content, increasing the percentage of dry matter and presumably increasing the power of imbibition with which the remaining moisture is held by the leaf cells. Rather tender cabbage plants, the roots of which were placed in 8 percent sucrose solution, wilted quickly, indicating withdrawal of water from the upper portion of the plant, or at least stoppage of intake to make up losses by transpiration.

Resumé.—It does not necessarily follow from the water-loss theory of killing by cold that there is a definite minimum moisture content below which the protoplasm of all plants dies. In view of experiments such as those of Adams[3] and of Kiesselbach and Ratcliff[52] it seems quite likely that the minimum amount of water required by plant cells to retain life varies with the state of physiological activity, the stage of development, perhaps with changes in either internal or external conditions, and probably differs in various species at the same stage of development and under the same conditions. Ewart[135] has shown that some seeds can be dried to a moisture con-

tent of 1 or 2 percent without killing and there is reason to believe that if a tender cabbage leaf is killed by the loss of 50 percent of its water, a hardened leaf may be able to survive the loss of even a larger fraction at still lower temperatures. May not the hardening process in vegetable plants, the maturing process in woody stems and the ripening process in seeds involve changes which increase the stability of the protoplasmic structure as well as changes which make for increased water-retaining power?

RATE OF WATER-LOSS BY TRANSPIRATION IN HARDENED AND TENDER CABBAGE.

It is a commonly observed fact that non-hardened vegetable plants wilt severely upon transplanting to the field and if conditions favor rapid transpiration or if the soil is dry they may die, due to excessive water loss. On the other hand, plants properly hardened by any of the methods mentioned in this paper withstand transplanting without serious wilting. To the practical grower the ability of hardened plants to survive transplanting without dangerous wilting is probably of greater importance than the increased cold-resistance developed by the hardening process. Plate 6, B and C, illustrates the marked difference in turgor of hardened and not hardened cabbage plants one day after transplanting to the field. These were potted plants, so the root systems were not disturbed much by transplanting.

Of interest in this connection are the observations of Bergen[7] on the rate of transpiration of a number of evergreens, as *Olea, Quercus* and *Pistacia,* compared to that of *Ulmus* and *Pisum sativum.* He found that the water loss in the former group was 25 percent less than in the latter. He concluded, however, that xerophytic leaf structure (of the hardy evergreens) is not always incompatible with abundant transpiration, but sometimes exists only for use in emergencies, to protect the plant from injurious loss of water.

Salmon[108] draws attention to the xerophytic structure of the hardiest types of winter cereals; winter rye, Turkey and Kharkoff wheats are characterized, for example, by a narrow leaf and prostrate habit of growth. The same is true of Winter Turf, the hardiest variety of winter oats. Salmon found no differences in cell structure, epidermal covering, or mechanical ability to control transpiration, that could be correlated with the great difference in hardiness known to exist in cereals, except that Turkey wheat (hardy) had 25 percent greater root length than Fultz (less hardy) and 40 percent greater than oats and barley (least hardy). This character might enable the

plant to escape dangerous drying out when the ground is frozen to a certain depth.

The relation existing between water-retaining power and resistance to cold is demonstrated by observations of workers[53] in the United States Forest Service, in a recent study of a chlorosis of conifer seedings. The chlorotic leaves were less turgid than normal leaves and wilted very quickly when the water supply was cut off; in fact, chlorotic leaves of the Douglass fir wilted so quickly that accurate leaf measurements could not be made. Plants having chlorotic leaves failed to harden properly in the fall, so that many were injured by early fall frosts and many more by winter cold. However, in plots where the chlorosis was corrected in summer by spraying with ferrous sulfate, the plants became perfectly winter-hardy. Evidently chlorotic leaves are unable, because of absence of chlorophyl, to develop the usual water-retaining power and cold resistance of the species.

It was considered desirable to determine the difference in rate of transpiration of non-hardened plants and plants hardened in various ways, because of the indications which might be obtained thereby as to the relative water-retaining power of plants of different degrees of hardiness. Four experiments were performed, using cabbage plants in 4-inch clay pots. The pots were coated and sealed with a mixture of paraffin, vaseline and beeswax. Two to four plants were used from each experimental lot. Before sealing, the pots were brought to uniform moisture content. The experiments were conducted under different conditions, but in each experiment the plants were kept uniform with reference to external factors. Plants as nearly the same size as possible were used, but the hardened plants were usually smaller than the non-hardened. At the conclusion of each experiment the plants were weighed at once and the leaf area of each plant was measured with a planimeter. The results of the four experiments are presented in Table 10.

TABLE 10.—TRANSPIRATION EXPERIMENTS WITH CABBAGE PLANTS.

Treatment of plants	No. plants used	Av. leaf area per plant	Av. Amt. transpired per plant	Transpiration in grams per hour: per plant	Transpiration in grams per hour: per sq. M. leaf area
Expt. 1 (outdoors) 3/15/21 partly cloudy, cool, moderate wind, 24 hours					
Dry-grown gh. plants	4	125.0 sq. cm.	13.15 g.	0.547	43.7
Wet-grown gh. plants	2	354.0	39.6	1.649	46.6
Expt. 2 (In cool greenhouse) 3/15/21 temp. 60–70 degrees F., 24 hours					
Dry-grown gh. plants	4	167.0	12.95	0.539	32.3
Wet-grown gh. plants	2	285.0	27.9	1.162	40.8
Expt. 3 (In warm greenhouse) 3/19/21 temp. 65–80 degrees F., 24 hours					
Coldframe hardened for 5 days	2	347.0	34.60	1.441	41.5
Dry-grown gh. plants	4	165.0	19.22	0.800	48.5
Wet-grown gh. plants	2	315.0	41.15	1.714	54.4
Expt. 4 (Outdoors) 4/2/21, clear, warm, little wind, 5 hours, 11:30 A. M. to 4:30 P. M.					
Coldframe hardened for 1 week	2	278.3	18.90	3.778	135.6
Med. dry-grown gh. plants	3	202.0	12.97	2.590	128.3
Med. wet-grown gh. plants	2	395.5	29.6	5.920	150.0
Greenhouse plants grown in compost soil and watered with M/10 NaCl (hardy)	2	153.6	10.5	2.100	136.6
Same, watered with tap water (tender) ...	2	164.0	15.9	3.180	193.9
Greenhouse plants grown in sand, and watered with tap water (tender)	2	252.8	23.9	4.780	189.0

The water loss per square centimeter of leaf area per hour is somewhat greater in tender plants than in those hardened by drying, by coldframe exposure, or by watering with salt solutions. The much greater total water loss of the non-hardened plants was due to a large extent to the fact that they were larger than the hardened plants, though of the same age.

The fact that the rate of transpiration per unit of leaf area was less in hardened plants is significant. If the rate of diffusion of water from the cells into the intercellular spaces determines the rate of transpiration, then a lower rate of transpiration would be associated with a greater water-retaining power on the part of the plant cells. This water-retaining power would be exerted when the plant's cells are exposed to water loss by freezing in the same way as when exposed to loss by transpiration or by drying.

RATE OF DEHYDRATION IN HARDENED AND TENDER PLANTS.

Since it was found that hardened plants exhibited a greater water-retaining power than non-hardened plants upon freezing, it was thought that the difference might be measured by the rate of water loss in similar tissues exposed to drying.

Mr. V. R. Boswell[8] undertook a special investigation of the rate of dehydration of leaves from hardened and non-hardened plants during the winter and spring of 1921. The material used in his experiments was from the same lots upon which other results are reported in this paper.

Leaves of uniform condition and from corresponding parts of plants were gathered from cabbage and tomato plants subjected to various hardening treatments. Lots directly comparable were gathered and dried at the same time. The samples were placed in stoppered bottles, taken at once to the laboratory, weighed, and immediate-

TABLE 11.—RATE OF WATER LOSS BY DRYING AT 60°C. IN HARDENED AND TENDER LEAVES.
(In per cent of total moisture content)

Time in minutes	Tomato leaves		Cabbage leaves				
	Greenhouse wet-grown (tender)	Hardened in cold-frame	Greenhouse wet-grown (tender)	Hardened in cold-frame	Greenhouse plants: water (tender)	Greenhouse plants: $NaNO_3$ (medium hardy)	Greenhouse plants: NaCl (hardy)
15	34.77	26.46	21.53	8.92	23.82	19.70	12.13
30	68.11	57.91	42.71	17.43	46.71	38.68	24.29
45	83.99	75.34	54.20	36.83	62.74	54.80	34.68
60	94.27	87.85	75.32	47.56	74.81	66.27	43.13
75	97.94	95.57	79.08	55.23	84.67	76.42	51.99
90	99.34	99.02	93.32	68.23	91.59	83.20	59.36
105	99.59	99.52	93.12	74.58	96.32	89.27	66.79
120	99.62	99.61	99.66	86.01	98.73	93.94	73.34
135	99.64	99.63	98.11	94.88	99.68	97.57	78.87
150	.....	.....	99.80	94.73	99.93	99.37	84.48
165	.....	.....	.....	98.88	99.95	99.87	88.91

ly placed in an electric oven at a constant temperature of 60°C. The leaves were spread out on wire gauze placed on the shelves of the oven until they were beginning to become brittle, after which they were transferred to the weighing bottles in which the dehydration was completed. Each lot of leaves was removed from the oven at intervals of 15 minutes, cooled and weighed. From the loss in weight for each period of drying, was calculated the percent of total moisture removed per period. Table 11 compiled from some of Boswell's data, gives the percent of total moisture lost at the end of each 15-minutes interval in samples of hardened and tender plants.

The data presented in Table 11 bring out a striking difference in the rate of water-loss by drying in hardened and non-hardened leaves of cabbage, especially at the beginning of the period of drying. This difference is not very great in the two lots of leaves of tomato. In cabbage, leaves from plants hardened by exposure in the cold-frame, by watering with salt solutions and by partially withholding water, show a much smaller loss of water for each period than do leaves of tender, well-watered plants grown in the greenhouse. This difference in rate of drying indicates a relatively much greater water-retaining power in hardened plants. Whatever the differences in the two types of plant tissue are, the greater water-retaining power of the hardy tissue evidently does not depend entirely on the organization of living matter, but on the chemical and physical properties of the substances of which the tissues are composed.

Another point which may be seen from Boswell's dehydration experiments is that tomato leaves dry out much more rapidly than cabbage leaves. Even the hardened tomato leaves give up water faster than the leaves of non-hardened cabbage. In view of the fact that the tomato is not susceptible of hardening to the extent of surviving ice formation, it seems that we have here an indication of the fundamental difference between the two types of plants. The tomato lacks the potential ability to acquire or develop increased water-retaining power to any great degree, while the cabbage and similar plants have this potentiality to a considerable degree.

Figure 7 shows graphically the relative rate of water-loss by drying in the different types of tissue.

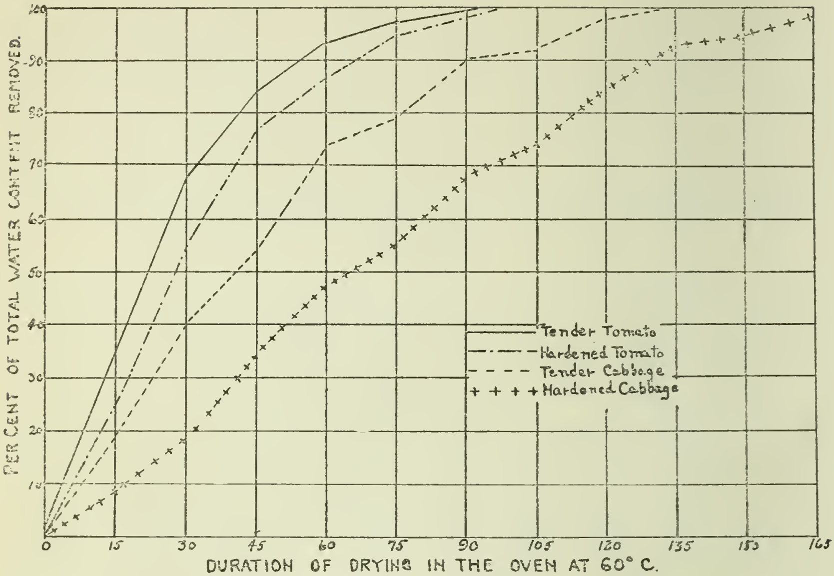

Fig. 7.—Rate of water loss from leaves of varying degrees of hardiness.

CHANGES IN CARBOHYDRATES ON HARDENING OF PLANTS.

Formation of sugar by low temperature.—Numerous investigators have noted increased amounts of sugars in plants exposed to low temperature. Mer[67] was probably the first to note the disappearance of starch and the accumulation of sugar in evergreen leaves in winter.

Lidforss[60] noted in a number of evergreen plants in Sweden that starch was converted to sugar in the fall and reconverted into starch in spring. He found that tender seedlings placed in a sugar solution for a short time were able to withstand several degrees of lower temperature without injury. Lidforss thought the hardiness of the evergreen leaves and the sugar-treated seedlings was due to increased concentration of the cell sap resulting from the accumulation of sugar, to which he attributed reduced transpiration and lower freezing point depression, as well as a protective effect of sugar on the precipitation of proteins of the cell. Gorke[35] found that he could prevent the precipitation of protein from expressed plant sap by adding sugar.

Miyake[70] examined the leaves of evergreen plants in various parts of Japan in winter finding those of many plants to be starch-free during the coldest part of winter. Another group had very little starch in the mesophyll during cold weather (when the mean temperature was near or below the freezing point.) Plants in Northern Japan were markedly lower in starch than in the warmer sections. Schulz[111] examined one hundred species of plants in Germany, finding most of them starch-free in winter, while a few contained a little starch mostly in the fibrovascular bundles and the surrounding cells.

Recently, Swedish investigators[2] have shown that the hardier varieties of wheat have a larger sugar content in fall and winter. They found that the percentage of dry matter and the amount of sugar in winter wheat varies considerably during the winter, fluctuating with the temperature, but during the period from November 12 to February 15, no starch could be found in the leaves. Gasner and Grimme[31] upon analyzing the first leaves of wheat, found that seedlings germinated at 5–6°C. had a greater sugar content than those germinated at 28°C. They also found a higher sugar content in leaves of hardy winter wheats than in spring wheats germinated at the same temperature.

Micheal-Durand[69] in extensive studies on the changes of carbohydrates in plants, found an enormous accumulation of sugars in leaves of certain evergreens in winter, while starch completely disappeared during the coldest weather. He explains this condition as follows:

(1) In winter assimilation is low, but respiration is depressed still more by the low temperature.
(2) Conditions in winter are unfavorable for translocation.
(3) Low temperature prevents the condensation of the simple sugars into higher carbohydrates.
(4) Breaking up (splitting) of polysaccharides.

Müller-Thurgau[75] and others, have measured the accumulation of simple sugars in potatoes at the expense of starch upon exposure to low temperature and the reconversion of the sugars into starch when higher temperatures are provided. This reversible chemical change seems to be generally associated with changing temperatures near the freezing point, probably due to shifting of chemical equilibrium by enzymatic activity.

Relation of sugar content to cold resistance.—Since the experiments of Lidforss[60] and Gorke[35] the extensive formation of

TABLE 12.—CHANGES IN CARBOHYDRATE CONTENT OF PLANTS SUBJECTED TO HARDENING TREATMENTS.

Series No.	Treatment	Date sampled	Per cent on dry weight basis				Per cent on fresh weight basis				
			Reducing sugars	Total sugars	Starch	Total polysaccharides	Reducing sugars	Total sugars	Starch	Total polysaccharides	% Dry matter
	Cabbage										
A1	Grown wet, in greenhouse (tender)	11/22/19			4.222	10.31			0.363	0.954	8.6
		3/12/20	1.10	2.58	3.69	7.66	0.088	0.212	0.302	0.628	8.2
		12/10/20	1.25	1.63			0.127	0.165			10.18
A2	Grown medium dry, in greenhouse	11/22/19				9.56				1.121	11.71
		3/12/20	3.50	4.00	2.82	5.52	0.396	0.451	0.319	0.631	11.3
A3	Grown dry in greenhouse (hardy)	12/8/19			3.125	9.26			0.312	0.926	10.00
		3/12/20		4.67	2.19	6.24		0.597	0.281	0.798	12.80
		4/5/20				8.94				1.019	11.40
		12/10/20	5.50	6.62			0.651	0.784			11.85
A4	Water partially withheld for 2 weeks (in greenhouse)	3/12/20	2.25	3.42	2.50	7.82	0.242	0.368	0.269	0.841	10.76
E4	Greenhouse plants, not hardened	3/22/20	1.78	3.58	3.13	7.13	0.187	0.376	0.329	0.748	10.52
		4/5/20				8.25				0.774	9.38
E3	Hardened in coldframe 1 week	3/20/19	8.74			1.422	0.986				11.28
		11/22/19	8.870	10.670	2.037	8.00	1.040	1.250	0.239	0.938	11.71
		3/22/20		6.00	3.44	7.26		0.738	0.424	0.893	12.31
E2	Hardened in coldframe 2 weeks	3/20/19		11.44				1.514			13.24
		3/22/20	8.26	10.75	0.72	8.26	1.067	1.388	0.093	1.067	12.91
		12/10/20	4.87	8.59			0.614	1.084			12.62
E1	Hardened in coldframe 3 weeks	11/22/19	3.316	4.75	2.319	10.31	0.416	0.596	0.291	1.295	12.55
		12/8/19		4.66	1.444	9.31		0.515	0.159	1.028	11.05
		3/22/20	5.65	11.00	trace	6.59	0.751	1.461	0.000	0.874	13.27
		4/5/20	6.44	9.54		6.25	0.794	1.176		0.771	12.33
	Lettuce										
A1	Greenhouse plants grown wet (tender)	10/31/19	1.195	5.67	8.06	8.25	0.066	0.317	0.445	0.454	5.52
A3	Greenhouse plants grown dry (hardy)	10/31/19	2.095	8.10	7.25	9.36	0.138	0.532	0.476	0.614	6.56
B6	Greenhouse plants grown in rich soil (very tender)	10/31/19	1.350	6.17	8.20	8.87	0.072	0.328	0.436	0.472	5.32

TABLE 12.—(Continued)

Series No.	Treatment	Date sampled	Per cent on dry weight basis: Reducing sugars	Total sugars	Starch	Total polysaccharides	Per cent on fresh weight basis: Reducing sugars	Total sugars	Starch	Total poly-saccharides	% Dry matter
	Cabbage										
B2	Greenhouse plants grown in poor sandy soil (med. hardy)	10/31/19	1.870	8.17	5.82	7.145	0.096	0.420	0.299	0.367	5.13
X1	Greenhouse plants (very tender)										
	old plants	11/29/19	0.709	3.008		6.63	0.028	0.121		0.264	3.98
	young plants	3/24/20	6.603	9.50	3.56	7.72	0.521	0.746	0.280	0.605	7.85
	older plants	12/10/20	1.66	7.92			0.102	0.485			6.115
X2	Coldframe plants										
	old plants	11/29/19	2.880	7.113	2.25	7.50	0.202	0.499	0.158	0.527	7.02
	young plants	3/24/20	8.00	20.00	3.37	8.19	0.840	2.100	0.354	0.860	10.50
	older plants	12/10/20	5.35	13.75			0.340	0.874			6.38
	Head Lettuce										
	Hardened in coldframe										
	young plants	3/24/20	4.94	22.32		5.59	0.556	2.487		0.622	11.13
	old plants	12/10/20	3.94	16.00			0.392	1.594			9.97
	Cauliflower										
E2	Greenhouse plants not hardened	3/24/20	5.00	8.25		10.42	0.593	0.982		1.240	11.9
E1	Hardened in coldframe	3/24/20	7.31	10.42	1.69	8.69	0.981	1.374	0.226	1.174	13.4
	Tomato										
A1	Wet-grown greenhouse plants, tender	5/3/19				3.37				0.419	12.41
		9/21/19	0.788	3.42	5.87	8.32	0.065	0.285	0.488	0.691	8.29
A3	Dry grown greenhouse plants, hardy	5/3/19		1.80		7.54		0.320		1.346	17.78
		9/21/19	1.236	2.85	14.18	16.61	0.135	0.313	1.56	1.711	11.00
E5	Greenhouse plants not hardened	5/3/19	2.295	3.457	3.56	4.598	0.324	0.488	0.502	0.662	14.1
E3	Hardened in coldframe, 10 days	5/3/19	1.257	2.295	12.0	27.45	0.184	0.335	1.755	4.010	14.6
E1	Hardened in coldframe, 20 days	5/3/19	2.08	2.83		23.28	0.288	0.406		3.416	13.85

sugars in leaves of plants exposed to cold has generally been considered to be related to their cold-resistance. However, Harvey[42] concluded that carbohydrate changes were not important in the hardening process with cabbage plants, since he found that cabbage plants could be hardened to some extent at least, by keeping them several days in the dark in a low temperature chamber, during which time there was little change in the carbohydrate equilibrium. However, it has been shown by several investigators and notably by Lewis and Tuttle[59] that simple sugars form a large part of the osmotically active cell contents.

From the beginning of these experiments, samples were collected for carbohydrate analyses from some of the series of plants in each of the hardening treatments. The results of some of these determinations are given in Table 12.

Methods of analysis.—The sugar analyses were made according to the modified Munsen and Walker method, as described by Hooker,[46] the results being expressed as dextrose.

One gram of the air dry, ground plant material was weighed, transferred to filter paper and washed thoroughly five times with distilled water. The insoluble residue was used for the starch determination. The filtrate, amounting to about 150 cc., was taken for determination of soluble sugars. After clearing with basic lead acetate the extract was made up to 250 cc. and filtered. Two hundred cc. of the filtrate was pipetted into a volumetric flask, excess lead precipitated with solid sodium carbonate, made up to 250 cc. and filtered. An aliquot of the filtrate (Solution A) was used for the determination of reducing sugars, while another portion was used for determination of the total sugars.

Five cc. of concentrated HCl was added to 75 cc. of Solution A and hydrolized at 70°C. for exactly ten minutes (Solution B). After cooling, this solution was neutralized with sodium hydroxide made up to 100 cc. and used for the determination of total sugars as dextrose.

The sugar-free residue of the original sample was used for the starch determination. It was washed into a beaker, boiled five minutes to convert the starch into a paste and after cooling 3 cc. of Taka-diastase solution were added. The beaker was then placed in the oven at 40°C. for 24 hours, the starch being broken down to maltose and dextrin. The liquid containing these sugars was then filtered off, adding the washings to the filtrate, which was hydrolized with acid for 2½ hours under a reflux condenser to break down further the products of digestion to dextrose. After cooling, the solution was neutralized with sodium hydroxide, cleared and prepared for analysis as previously described. A blank with the same amount of Taka-diastase solution was run with each series of starch determination.

Total polysaccharides were determined on a sample of the dry plant material washed free of soluble sugars with cold water. The filter paper was punctured and the residue washed into a 700 cc. flask. Eight cc. concentrated HCl. and enough water was added to bring the total volume to 150 cc. After boiling two and one half hours under reflux condenser, the contents of flask were cooled, transferred to a beaker and made neutral to litmus with sodium hydroxide. The solution was then prepared for analysis as previously described for Solution A.

Discussion.—Table 12 presents evidence that: (1) The content of both reducing and total sugars increases in hardened plants. This increase seems to be greater in plants hardened by exposure to low temperature in the coldframe than in plants hardened by other methods. The increase in sugar is greater in hardened cabbage and lettuce than in the tomato, though there is no direct evidence that the absolute quantity of sugars present in the plant is directly related to its cold-resistance. Thus some of the tender lettuce samples have more sugar than certain samples of hardy cabbage. Young lettuce plants contained much more sugar than plants approaching maturity and this may have something to do with the greater cold-resistance Chandler[20] found in the younger leaves of lettuce, whereas in most plants the young leaves were somewhat more tender to cold.

(2) In lettuce, cauliflower and cabbage the amount of total polysaccharides is usually somewhat less in hardened than in non-hardened plants, which decrease may be attributed to the reduction in the amount of starch. In the tomato, on the other hand, the total polysaccharides show a large increase, apparently due mostly to the deposition of starch in large quantities in both stems and leaves of plants exposed to any of the hardening treatments. Kraus and Kraybill[54] found a similar increase of starch in tomato plants in a stunted condition. Hartwell[43] found a large accumulation of starch in plants, especially the potato, when the growth was checked by any limiting factor.

Here is an interesting distinction between the chemical changes in a group of plants susceptible of considerable hardening to cold and a plant not susceptible of much hardening. In the group of plants possessing potential hardiness, exemplified by the cabbage, any hardening treatment causes a considerable increase in sugars and a decrease in starch, while the total polysaccharide figure remains nearly constant (on the fresh weight basis) because, as will be shown later, of an increase in pentosans. On the other hand in the tomato, lacking potential hardiness, the hardening treatments caused only a slight increase in the sugars and an enormous increase in polysaccharides due mostly to an increased starch content.

An increased sugar content in the hardened plants would increase the osmotic concentration of the cell sap, depress the freezing point and perhaps serve to hold a somewhat larger amount of water in the unfrozen state when the plant is exposed to low temperatures. However, the importance of the increased content of sim-

ple sugars in cold resistance remains undetermined, nor is it known to what extent sugars may be responsible for the greater water-retaining capacity of hardened tissues. It appears probable that an increased sugar content in hardened plants is more likely one of the manifestations of the condition of being hardy than a direct cause of cold resistance.

NATURE OF WATER-RETAINING POWER IN PLANTS.

It has been shown by experiments with the dilatometer that: (1) the amount of water frozen in hardened cabbage plants is considerably less than in tender plants, (2) the increase in the amount of water frozen as the temperature is lowered becomes less and less, probably approaching zero, (3) the amount of water freezing at a given temperature (–5°C.) decreases as the degree of hardening increases. It has also been shown that hardened plants have a lower transpiration rate and that hardened tissues dry out more slowly than tender tissues. The greater water-retaining power of the cells of hardened plants must therefore be accepted as a fact. What factors are responsible for the development of this increased water-retaining power?

Several investigators have attached great significance to the osmotic concentration of the sap as determined by the depression of its freezing point. Some data are also presented in this paper (Table 2) showing that in hardened plants this depression is greater than in non-hardened plants. However, concentration of the sap, even if entirely due to substances having a low eutectic point, would not be sufficient to account for the amount of water found to remain unfrozen in hardened plants (Table 3). Moreover, some of the sap solutes have a high eutectic point, for Harvey[42] found numerous large crystals of calcium malophosphate in frozen spots on leaves exposed to temperatures not low enough to kill the whole plant. Some investigators have stated that the increased sugar content of plants in winter was at least to some extent responsible for their cold-resistance because of the increased concentration thereby imparted to the cell sap. The highest percentage of total sugar found in cabbage in these experiments (Table 12, 1.461 percent in Series E1, gathered March 22, 1920,) is equal to only 1.68 percent sugar solution in the plant sap. Considering half of this sugar to be glucose and half sucrose, we have a sugar solution equivalent to less than 0.075 molecular. This would not be sufficient to affect materially the amount of water frozen in the plant tissue at a point several degrees

below 0°C., one gram-molecular weight of a non-electrolyte lowering the freezing point 1.86°C.

It has been further pointed out (p. 35) that the greater depression of the freezing point in hardy tissues is associated with certain changes in the plant cell upon hardening, the apparent increase in sap concentration being simply an accompaniment, rather than a cause of increased hardiness. It therefore is necessary to introduce some other factor to explain the difference in amount of water freezing in hardy and in tender tissues. It has been indicated that the force of imbibition may be a powerful factor in withholding water from freezing. This force varies inversely to the water content, but probably increases more rapidly than the rate of decrease in water content, as indicated by the slow rate of drying leaves and of colloidal materials after they have been dried out to a certain extent. It is a pretty well recognized fact that tissues with lower water content are more resistant to killing by cold.

Plant protoplasm is not a compound of definite chemical composition or even constant physical condition, but a colloidal mixture of the emulsoid type varying in consistency from a hydrosol to that of a hydrogel and containing different substances which may be present in greater or less amounts at different times and in different organs. According to Seifriz,[113] the change from one state to another is dependent upon, or coincident with, changes in physiological activity. Thus, in the eggs of *Fucus,* he found a progressive increase in viscosity with decreasing physiological activity. Strausbaugh,[117] as a result of recent investigations on the plum in Minnesota, suggests that the prolonged dormancy and water-retaining power which he found in hardy varieties is due to a change in colloidal properties creating an increased power of imbibition. The work of these investigators is significant, since hardy plants are usually at a low state of physiological activity at the time of their greatest cold resistance.

Water of imbibition may be held by molecular capillarity or in the absorbed condition by the hydrophilous colloids of the plant cells. Such water is not readily available for freezing, in other words, the force with which it is held must be overcome by a considerable force of crystallization before it can be drawn from the cell and frozen. Mc Cool and Millar[80] have suggested the classification of plant moisture as "free' or easily freezable and "unfree" or not easily freezable, somewhat as Bouyoucos has classified soil water. Such a classification necessitates setting an arbitrary temperature of freezing, the

relative amounts of free and unfree water varying with the temperature at which freezing takes place. Yet it is convenient for our present purpose to refer to free and unfree water in the sense that the latter, for one reason or another, remains unfrozen at a given temperature.

It seems from the work of Bouyoucos[10] and of McCool and Millar[80] that the unfree water is held to a very large extent in the adsorbed condition by protoplasmic colloids. The water-retaining power of colloids and the quantity of certain colloidal materials in the cell are thereby suggested as an explanation of increased water-retaining power and cold-resistance in plants.

Relation of pentosan content to cellular water-retaining power. —Spoehr's work[116] on cacti suggests that pentosans may be the specific substances which increase the water-retaining power in hardened plants. He found that the pentosan content of *Opuntia* increased considerably under xerophytic conditions and suggested that the large water-retaining power of the pentosans is largely responsible for their well-known ability to survive under such circumstances. The work of Livingston[138] and others has shown that the osmotic pressure in cacti and other desert plants is no greater than in many mesophytes, hence this factor probably plays only a small part in the water-holding power of most xerophytic plants.

Spoehr found by analysis of desert plants that in cells undergoing water depletion, other polysaccharides were changed to pentosans, of which the plant mucilages are largely composed. Thus, "undue loss of water caused a change in the cell whereby the amount of water it may hold is greatly increased." Mac Dougal[86] considers a change of this sort to be the basis of xerophytism. Water of imbibition was found by Spoehr to be closely related to the presence of the pentose polysaccharides. Pentosan formation increased decidedly with low and decreased with high water content. From April till June, while the weather was very dry, pentosans made up from 9 to 12 percent of the dry weight. During the rainy weather of July, the pentosan content fell to 4.39 percent of the dry weight, increasing to 12.5 percent again in the dry cool weather of the fall and falling to 4.37 percent when the winter rains set in.

Not all cacti possess a large pentosan content. Spoehr gives analysis of two species of *Opuntia* growing at Tucson, as follows:

	Fresh weight basis				
	% water	% total sugars	% total polysach.	% total pentose	% pentosan
O. Versicolor	82.15	1.97	1.50	0.36	0.230
O. Phaeacantha	78.70	3.53	3.22	1.64	1.550

In view of this difference in composition, it may be significant that *O. Phaeacantha* is listed in Bailey's Encyclopedia of Horticulture as a hardy variety and is reported by Shreve to grow in the mountains about Tucson to an altitude of 7500 feet.

A striking property of the pentosans is their power of swelling and taking up an enormous amount of water, which the hexose polysaccharides do not do to nearly so marked a degree. The occurrence of pectins in the middle lamella of the cell walls is well known. Spoehr believes that they are also distributed through the protoplasm and are used for a variety of purposes. The plant nucleo-protein has been found by Levine and Jacobs[136] to contain the pentose group as part of the nucleic acid radical. Tollens[137] showed that pentosans were widely distributed in plants and were limited to no special tissue, but abundant in roots, stems, leaves and seeds. He found further that pentosans showed all possible variations as to solubility in water. Swartz[119] obtained a water-soluble pentosan from *Dulce*. In the crude form, this was very hygroscopic, but this property was lost after several purifications. She found that the hemi-celluloses of ten species of marine algae were chiefly pentosans and galactans and concluded that pentosans and hexosans very commonly occur together, not only intimately associated, but chemically combined. Mac Dougal[81] goes so far as to state that the "plant protoplasm consists of a comparatively inert base of pentosans—in colloidal combination with proteins, amino acids, lipins, and salts."

As to the origin of pentosans, Spoehr[116] shows that pentoses can be formed from the hexosans as the first product of oxidation. This view is corroborated by the work of Ravena and Cereser,[102] who found no marked variation in pentosan content during the period of photosynthetic activity, but when the carbohydrate food consisted entirely of dextrose, the amount of pentosans increased greatly, especially in light. The probability of pentosan formation from the hexosans is indicated also by the increased pentosan content in the presence of high total sugar and diminishing starch, as shown later in this paper.

Davis, Daish and Sawyer[24] found no diurnal variation in the pentosan content of plants. However, they found that the amount of pentosan in the leaf of the Mangold (*Beta vulgaris*) increased from August to October.

Hornby[48] found that the pectin content varied in different parts of the same plant. More pectin was found in the epidermal tissue than in the cortex. Exposure to light, and mechanical injury to

tissues, were found to result in increased pectin content in the exposed or injured part. Hornby suggested that pectin might have a protective effect on plants, especially against insect attacks.

Hooker[47] has shown that the hardier parts of apple shoots, the bases, have a greater water-retaining power than the tips, which are less cold-resistant. He placed portions of the air-dried ground material in desiccators containing sulfuric acid, the concentration of which ranged from 100 to 36.69 percent. The air-dry material lost moisture in the desiccators containing the higher concentration of acid and this loss was greater in the tender material. But over the lowest concentration of acid used, water was taken up, the gain in weight being greater in the hardy material. This experiment indicates that hardy apple twigs contain a larger amount of some hygroscopic material. Hooker attributed the greater water-retaining power of the hardy tissue to the larger percentage of total pentosan found therein.

Pentosan content in the hardening process in vegetable plants.—In this work, a study was made of the pentosan content in an effort to throw light on the nature of the increased water-retaining power of hardened plants. For the pentosan determinations, samples were taken from plants grown under the various hardening treatments previously described. Also a series of analysis were made on plant material gathered from the field at intervals during the fall of 1920.

Method of Pentosan Analysis.—The method of analysis was that employed by Spoehr.[116] A two gram sample of the oven-dry material was hydrolized by boiling for three hours with eight cc. concentrated HCl in 150 cc. water. After cooling, the entire contents of the flask containing the products of hydrolysis were transferred to a 400 cc. baker, neutralized with NaOH, a uniform amount of a suspension of yeast was added and the beakers placed in an oven at 35–40°C. over night. The hexose sugars were fermented off, leaving the non-fermentable pentose sugars in the solution. After fermentation the material was filtered and washed, the filtrate containing the pentose sugars was boiled ten minutes to drive off the alcohol, then prepared for analysis in the same way as described for sugar determinations. The result obtained was calculated from Munson and Walker's tables, multiplying the glucose value by 0.85, since Spoehr found that the reducing value of the pentose sugars held that relation to glucose. The results on total pentosan content are given in Table 13.

TABLE 13.—TOTAL PENTOSAN CONTENT OF PLANTS FROM VARIOUS HARDENING TREATMENTS.

Serial No.	Treatment	Cabbage Date sampled	Cabbage on fresh wt. basis	Cabbage on dry wt. basis	Tomato Date sampled	Tomato on fresh wt. basis	Tomato on dry wt. basis	Leaf Lettuce Date sampled	Leaf Lettuce on fresh wt. basis	Leaf Lettuce on dry wt. basis
A1	Grown in greenhouse, optimum moisture, (tender)	12/18/19	.289%	4.06%	5/3/20	0.693%	7.10%	10/5/20	0.106%	2.12%
		3/12/20	.243	2.97	4/30/21	0.382	3.93			
		3/22/20	.352	4.59	12/12/19	0.341	2.65			
		3/22/20	.323	4.42						
		3/16/21		3.61						
	(light shade)	3/19/21	.160	2.55						
A2	Medium moisture	3/12/20	.320	2.82	5/3/20	0.795	5.39			
		12/10/20	.429	4.21	4/30/21	0.401	3.67			
		3/19/21	.527	5.26	9/21/19	0.455	5.10			
					10/16/19	0.798	6.11			
A3	Minimum moisture (hardy)	11/20/19	.541	4.41	5/3/20	0.720	4.56	10/5/20	0.402	4.31
		12/18/20	.583	5.83	4/30/21	0.575	4.68			
		3/12/20	.423	3.30	12/12/19	0.596	2.47			
		3/22/20	.540	5.15	12/12/19	0.548	4.68			
		3/22/20	.623	8.19	10/16/19	0.780	6.11			
		4/5/20	.563	4.94						
		12/10/20	.631	5.32						
		3/16/21	.525	5.00						
		3/19/21	.519	4.94						
A4	Water withheld 2 weeks	3/12/20	.412	3.83	5/3/20	0.598	4.54	10/5/20	0.564	6.489
		3/19/21	.527	5.37	9/21/19	0.464	4.41			
E4	Greenhouse plants, not hardened	3/22/20	.207	1.97	5/3/20	0.384	3.45	11/29/19	0.131	3.29
		4/5/20	.195	2.09				3/24/20	0.126	1.61
		3/29/21	.290	4.25						
E3	Hardened in coldframe, 1 week	3/19/21	.442	4.12	4/30/21	0.556	4.62			
		3/22/20	.413	3.35						
E2	Hardened in coldframe 2 weeks	12/8/19	.588	5.31	5/3/20	0.682	5.31	3/24/20	0.230	2.19
		3/22/20	.530	4.10	4/30/21	0.575	4.68	3/24/20	0.568	5.10
		12/10/20	.662	5.24					(head lettuce)	
E1	Hardened in coldframe 3 weeks	3/22/20	.810	6.10	5/3/20	0.362	2.93			
		3/19/21	.522	5.20	4/30/21	0.581	4.09			
E0	Hardened in coldframe 4 weeks							11/29/19	0.295	4.20
		4/5/20	.654	5.301	4/30/21	0.562	4.41	10/31/19	0.369	4.20
E00	Hardened in coldframe 5 weeks	3/16/21	.776	5.84						

Plants not hardened by any special treatment are low in total pentosans and hardened plants have a much larger amount, in some cases in cabbage an increase of about 200 percent. Plants given intermediate hardening treatments have a medium amount of pentosans. The increased pentosan content of the hardened plants is most striking if we consider the results on the fresh weight basis. This probably is the most suitable criterion to use in a study of the reactions which concern the living plant, especially since Parker has shown that the force with which water is held by finely divided materials depends largely on the moisture content.

It may seem that the absolute amounts of pentosans, even in the hardened plants, are too small to influence very markedly the force with which the cells may retain water under conditions of stress. However, it should be borne in mind that in nature the pentose molecule probably exists in combination with four molecules of galactose or other hexose sugar. Hence the amount of pentosans in the plant is much greater than the analyses indicate.

Pentosan content of garden plants.—Samples of leaves were gathered at intervals during the fall from cabbage, kale and celery plants growing in the open field. The seed had been sowed in July and the plants made considerable growth before the first light frost came on October 1. The month of October was mild, and the plants remained alive until heavy freezes the last of November. Exposed to steadily declining seasonal temperatures, these plants may be considered to have undergone a kind of hardening treatment, for they were able to withstand light frost in October and heavy frost the early part of November. The results of the total pentosan determinations are given in Table 14.

TABLE 14.—TOTAL PENTOSAN CONTENT OF GARDEN PLANTS IN AUTUMN.

Date sample collected	Kale		Cabbage		Celery	
	% of fresh wt.	% of dry wt.	% fresh wt.	% dry wt.	% of fresh wt.	% of dry wt.
Sept. 15			0.289	4.06		
Oct. 7	0.511	3.93	0.580	4.36	0.567	4.42
Oct. 20	0.528	4.89	0.545	4.73	0.801	4.26
Nov. 3	0.537	3.93	0.621	4.36	0.793	4.44
Nov. 10	0.722	4.95	0.782	5.31	1.029	5.58
Nov. 18	1.064	6.48				

Table 14 shows that the total pentosan content of these plants becomes high when they are exposed to cool weather during the late

fall. The pentosan content on the fresh weight basis increases fairly regularly up to date of last sampling.

Pentosan content in plants watered with salt solutions.—An experiment wherein the hardiness of cabbage plants was considerably increased by watering them with M/10 salt solutions has been described. Plants hardened in this way were shown to have greater water-retaining power than unhardened plants. Samples from the salt treatment plots were analyzed for total pentosan content. The results are given in Table 15.

TABLE 15.—PENTOSAN CONTENT IN CABBAGE PLANTS HARDENED BY SALT SOLUTIONS.

Treatment of plants	Percent total pentosans	
	On fresh weight basis	on dry wt. basis
Compost soil, tap water	0.290	4.25
Compost soil, $NaNO_3$	0.471	5.05
Compost soil, KCl	0.451	4.24
Compost soil, NaCl	0.483	5.05
Sand, tap water	0.220	3.45
Sand, NaCl	0.288	4.25

The total pentosan content of the plants whose growth was checked by the application of the salt solutions and which were hardier to cold, show somewhat greater amounts of total pentosans on the dry weight basis and a considerable increase on the fresh weight basis, as compared to plants making a normal growth with tap water.

It appears from Table 15, that the pentosan content of the plants grown in sand is considerably lower than for plants grown in compost soil and receiving corresponding treatments. The plants grown in sand and receiving tap water were somewhat tenderer to cold than those grown in compost and likewise given tap water. Plants grown in sand and watered with M/10 NaCl show only a slight increase in pentosan content, as compared to plants grown in compost soil, likewise watered with M/10 NaCl. Here again, pentosan content shows a close correlation with the hardiness of the plants, as determined by freezing experiments.

Rate of increase in pentosan content.—The three groups of experiments just described having indicated a larger amount of pentosans in plants hardened in different ways, it was deemed desirable to determine their rate of development during the hardening process. Lots of potted cabbage plants were removed from the warm green-

house at intervals during March, and placed in an open coldframe. On March 19, samples were taken for analysis from all the lots which had been exposed to the hardening process for periods ranging from 3 to 20 days, as well as from some of the original lot which had been kept in the greenhouse under favorable growing conditions. The total pentosan content of the plants hardened for varying lengths of time is given in Table 16.

TABLE 16.—RATE OF INCREASE OF THE TOTAL PENTOSAN CONTENT IN CABBAGE PLANTS.

Treatment	Percent pentosan	
	On fresh weight basis	On dry weight basis
Greenhouse plants, not hardened	0.260	2.97
Hardened in frame 3 days	0.374	3.56
Hardened in frame 5 days	0.442	3.86
Hardened in frame 10 days	0.750	5.00
Hardened in frame 20 days	0.776	5.84

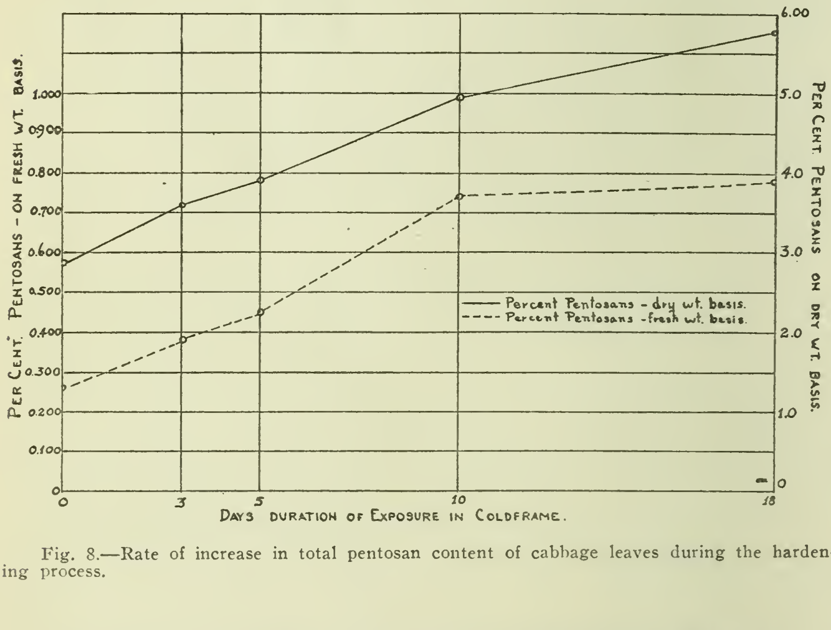

Fig. 8.—Rate of increase in total pentosan content of cabbage leaves during the hardening process.

The results of Table 16 are shown graphically in Figure 8. It appears that the increase in pentosan content proceeds quite rapidly and at a fairly uniform rate for ten days. After the first ten days of exposure in the coldframe the pentosan content increased only

slightly in this experiment. Other experiments have shown that the cabbage plant acquires nearly its maximum degree of hardening in this time. The dry matter content likewise increases rapidly the first few days of the hardening process, and more slowly thereafter.

In the dilatometer experiments, it was found that the amount of water frozen at –5°C. decreased with the duration of the hardening treatment in approximately the same order as the pentosan content is shown to have increased here. This seems to indicate a close relationship of pentosan content to water-retaining power and to cold resistance. The plants used in the dilatometer experiments were of the same lots as those from which the pentosan analyses were made.

TABLE 17.—RELATION OF HOT-WATER-SOLUBLE PECTINS TO TOTAL PENTOSAN CONTENT IN THE HARDENING PROCESS.

Treatment	Date sample taken	Percent pentosan on fresh weight basis		
		Total	Hot-water soluble	Insoluble (by difference)
Cabbage				
Wet-grown greenhouse plants	3/12/20	0.215	0.075	0.140
Dry-grown greenhouse plants	3/12/20	0.423	0.292	0.131
Greenhouse plants not hardened	3/22/20	0.207	0.091	0.116
Hardened in coldframe 2 weeks	3/22/20	0.530	0.408	0.124
Hardened in coldframe 3 weeks	3/16/21	0.776	0.550	0.226
Tomato				
Wet-grown in greenhouse	5/3/20	0.693	0.070	0.623
Dry-grown in greenhouse	5/3/20	0.720	0.071	0.649
Greenhouse plants not hardened	5/3/20	0.384	0.051	0.333
Hardened in coldframe 2 weeks	5/3/20	0.682	0.071	0.611
Sweet Potato				
Garden plant	10/7/20	0.477	0.127	0.350
Kale				
Garden plant	10/7/20	0.511	0.223	0.288
Garden plant	11/18/20	1.064	0.418	0.646
Celery				
Garden plant	10/7/20	0.567	0.236	0.331
Garden plant	11/10/20	0.793	0.423	0.370

Relation of hot-water-soluble pentosans to the hardening process.—In jelly-making a hot water extract of fruits is used. According to Goldthwaite[33] a cold water extract of our common fruits contains little or no pectin. The total pentosan determinations given in the four preceding tables indicate the larger content of pentosans in hardened plants, but in the total pentosans is included probably a more or less considerable amount of the insoluble hemi-celluloses of the cell wall, which might not be expected to function to any great extent as water-retaining material, though undoubtedly a part of the power of imbibition of the plant cell is due to its walls. The experience of jelly makers indicates that the hot water extract of fruit contained the most of the jelly-forming pectins. It was thought, therefore, that a hot water extract of the plant material would yield approximately that fraction of the total pentosan which exists in the protoplasm and might function as the significant water-retaining material.

Accordingly, analyses were made from some of the samples, varying the procedure from that described for the total pentosan determinations as follows: The weighed sample of dry material was transferred to a beaker with 150 cc. of distilled water. The slight acidity was neutralized by adding a bit of sodium carbonate, then the material was boiled for five minutes, and filtered hot through a Gooch crucible. This yielded a clear cherry-colored filtrate, containing all the hot-water-soluble pentosans, sugars, and other soluble carbohydrates. Hydrolysis, fermentation, clearing and analysis were carried out with this filtrate in the same way as previously described for the whole sample in the total pentosan determinations. The results are given in Table 17.

In cabbage plants exposed to hardening treatment, the water-soluble pentosans increase considerably while the insoluble (hemi-cellulose) fraction is nearly constant, regardless of the degree of hardiness. In hardened cabbage plants the amount of soluble pentosans is relatively large, in fact the increase in the total pentosan content is very largely due to the increase in the water-soluble fraction.

In tomatoes, on the other hand, the hot water soluble fraction is very small and does not increase much in plants subjected to hardening treatments. The relatively large amount of total pentosans in the tomato, therefore, is largely insoluble, probably existing mostly as hemi-cellulose or in the middle lamella. The sweet potato resembles the tomato, in that it has a relatively large total

pentosan content, but only a small soluble fraction. The sweet potato, like the tomato, is very tender to frost and is not susceptible of much increase in cold-resistance upon exposure to usual conditions of hardening.

The water-soluble fraction of the total pentosan content in garden plants of kale and celery is shown to increase considerably as they become hardier in the fall.

These differences in the soluble pentosan content may give us an important clue to the reason for the previously shown difference in cold-resistance, susceptibility to hardening and water-retaining power in the two groups of plants represented respectively by the cabbage and the tomato.

Factors influencing the imbibitional capacity of plant colloids.—In view of the increase in hardened plants of pentosans, especially in the hot-water-soluble fraction, and the possibility of these substances being at least partly responsible for the increased water-retaining capacity of such plants, factors which influence the water-retaining power of these and other hydrophilous colloids occurring in plants may be of great importance in relation to cold-resistance.

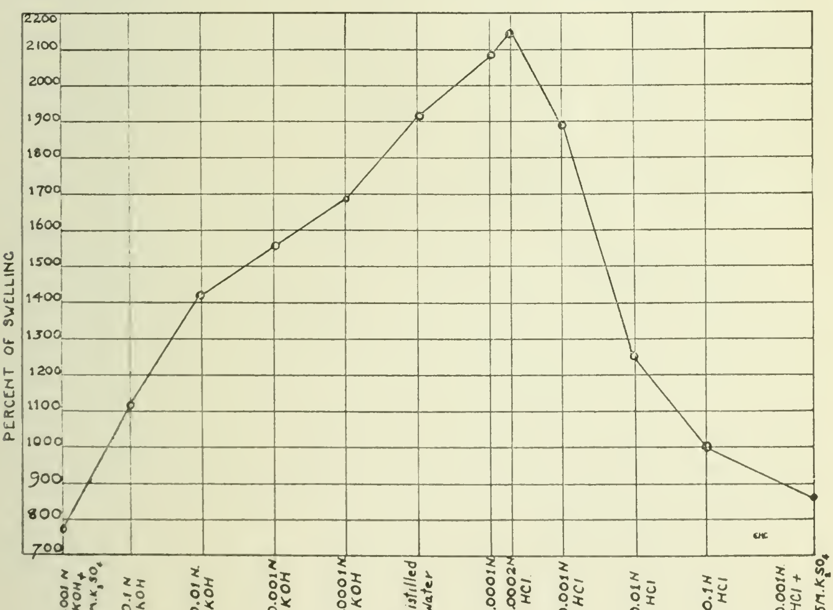

Fig. 9.—Swelling of Agar as influenced by reaction of the solution.

Acidity.—Fischer[30] showed that the power of imbibition of colloids was influenced very markedly by the reaction of the medium, as demonstrated by his experiments in which slight acidity increased the swelling of gelatin. He was able to alleviate oedema of the eye and other animal tissues by application of alkali and hypertonic sugar solutions. Fischer regards acidosis as one of the most important causes of the presence of abnormal amount of water in cells. Dachnowski[23] found that seeds of beans and corn swelled more and retained more water in N/800 acids than in water, but the amount of water absorbed and retained was not proportional to the concentration of acid, for a maximum was attained beyond which increased acidity decreases absorption. The addition of equi-molecular solutions of non-electrolytes, such as glucose and sucrose, did not increase the amount of water retained by seeds in Dachnowski's experiments. The amino-acid, glycocoll, was a striking exception in that greatly increased imbibition by seeds took place in the presence of this substance. Upson and Calvin[141] have shown that the mixture of vegetable proteins which comprises the gluten of wheat, behave in the same way as Fischer's animal proteins. They obtained maximum absorption of water in 0.01 N hydrochloric acid and 0.04 N acetic acid, with marked depression of absorption by strong acids and by salts. Mac Dougal and Spoehr[87] found a greater swelling of agar in N/100 solutions of the amino-acids glycocoll, alanin, and phenylalanin, than in water. The same workers have shown that the imbibition of proteinaceous colloids, such as gelatin, could be increased considerably by dilute acids, whereas colloids such as agar, having a pentosan base, swelled less in N/100 HCl than in distilled water.

However, brief series of tests made by the writer on the swelling of agar as influenced by the reaction, indicate that the greatest swelling of this material occurs in about N/5000 HCl. Presumably, it would require a much greater concentration of the plant acids to bring about the same degree of swelling as such a dilute HCl solution Alkalinity, excess acidity, and the presence of salts depressed the imbibitional capacity of agar very markedly. The results of a duplicate series of tests performed with shredded agar are presented graphically in figure 9.

The results obtained by Mac Dougal[82] indicate that a mixture of agar and gelatin would exhibit maximum swelling in somewhat stronger acid than would agar alone. Since colloids of the pentosan type probably occur in plants in intimate association with proteinaceous colloids, it is reasonable to suppose that the greatest power of

imbibition would be exhibited by plant cells in the presence of slightly increased acidity. Mac Dougal and Spoehr[88] suggest that the increased acidity found in succulent plants may be a characteristic of a metabolic complex favorable to pentosan formation and to the development of succulence (a high degree of water-holding power).

In connection with the increased water-holding power of some colloids, associated with slightly increased acidity and especially some of the amino acids, it is interesting to note that Harvey[42] found a marked increase in amino-nitrogen in hardened cabbage. May it not be possible that in developing hardiness, plants form some specific amino acid which would increase the water-retaining power of the cells?

Somewhat greater titratable acidity has been found in hardened cabbage, as shown in Table 18. Determinations of the hydrogen–ion

TABLE 18.—TITRATABLE ACIDITY IN HARDENED AND TENDER PLANTS.
(cc. N/10 NaOH per one gram dry material in 100 cc. water)

Treatment	Cabbage	Lettuce	Tomato (a)	Tomato (b)
Greenhouse plants, tender	1.60	1.86	0.96	1.74
Coldframe plants, hardy	2.06	3.06	——	1.74
In coldframe, 2 weeks	1.68	——		
Grown dry in greenhouse (hardy)	1.30	——	0.96	1.00
Grown wet in greenhouse (tender)	0.82	——	0.66	1.44

concentration were also made on a few samples, but little variation could be detected by the Gillaspie method.

It seems that there is a slight increase in acidity in plants as a result of the hardening process. This change may take place only in plants possessing potential hardiness such as cabbage and lettuce since the data in Table 18 indicate no correlation between acidity and hardening treatments in the tomato. Increased acidity might also influence the water-retaining power of plant cells to such an extent as to account at least partly for the cold-resistance of hardened plants, aside from any increase in the amount of hydrophilous cell colloids. However, too few data are available to draw a definite conclusion on this point.

Salts and sugars.—It has been shown by Fischer, Dachnowski, Mac Dougal and his co-workers that the addition of salts to a solution greatly decreases the imbibitional capacity of gelatin, seeds and

agar. However, Free[29] found that gelatin swells a little more in 0.5 percent solutions of dextrose and glucose than in water, while a distinct decrease of swelling occurred in solutions of 25 percent or over. Agar was found to swell a little more in two-percent sucrose than in distilled water, whereas dextrose had little effect, except that it depressed swelling in concentrated solutions. That dilute sugar solutions do not decrease the imbibitional capacity of such hydrophilous colloids as gelatin and agar is important, since a greater sugar content is found in hardened plants. According to Goldthwaite[33] pectin and acid are prerequisites for jellification of fruit-juice, while sugar is a necessary accessory. She was able to make an excellent artificial jelly with one percent pectin, 0.5 percent tartaric acid, and three-fourths volume of cane sugar. Furthermore, in her experiments, it was shown that increasing the proportion of sugar gave an increased volume of jelly. The work of these investigators suggests the possibility of increased acidity and sugar content playing an important part in determining the state of the colloidal protoplasm.

Perhaps sudden or extreme changes in some of these factors, which influence imbibitional capacity, might exert an important influence on the water-retaining power and cold resistance of plant tissue. However, the capacity of plant organs to take up or imbibe large amounts of water must not necessarily be taken as an index of their power to retain water when exposed to conditions favoring undue water loss, such as freezing or drying.

SUMMARY.

The work of previous investigators indicates that water-loss from the cells, by the formation of ice crystals in the intercellular spaces, is most generally the limiting factor in the killing of plant tissue by cold.

Any treatment materially checking the growth of plants increases cold-resistance. In cabbage and related plants, hardiness increases in proportion as growth is checked. In tomato and other tender species, the checking treatments resulted in relatively slight increase to cold-resistance. The various means of hardening plants in these experiments have resulted in about the same type of changes within the plant.

Cabbage plants hardened by various treatments contain a larger amount of "unfree," or not easily frozen water, as measured by the dilatometer. The increment in unfree water corresponds to the

extent to which growth is checked, both of these paralleling the degree of cold resistance.

The amount of water frozen at different temperatures in leaves of varying hardiness was measured. The percentage of moisture frozen in hardened cabbage leaves at –3°C. and at –4°C. is about two-thirds of that frozen in tender cabbage leaves at the same temperature. The actual amount of water remaining unfrozen at a given temperature is greater in hardened than in tender leaves, although their total moisture content is less.

The percentage of total moisture frozen in leaves increases for each successive degree of temperature lowering, but the increase becomes rapidly smaller and smaller. The amount of water remaining unfrozen in hardened cabbage leaves is approximately a logarithmic function of the temperature.

Cabbage plants exposed to low temperatures in a coldframe for varying periods have a progressively smaller amount of water freezable at –5°C., the longer they are exposed to hardening. The percentage of freezable water decreased quite rapidly in the first four days after removal from the greenhouse, more slowly from four to fourteen days and very slowly thereafter. The rate of decrease in percentage of freezable water coincides with the observed rate of hardening. In other words, the hardening process in cabbage plants was accompanied by a proportional increase in the amount of water unfrozen at –5°C. The amount of water frozen at –5°C. is somewhat less in plants exposed to slight wilting at midday.

The effects of watering plants with M/10 salt solutions are associated with a condition of mild physiological drought. The degree of such drought is proportional to the concentration of the soil solution, which in turn is influenced by: (a) the amount of water-soluble material present and (b) the power of the soil to hold a large part of the soil moisture unfree in the pure or nearly pure state.

Hardened cabbage plants lose less moisture by transpiration per unit of leaf area than tender plants, under the same conditions. The amount of water lost by transpiration per plant for a given period is much less in hardened cabbage plants than in non-hardened plants of the same age because of: (a) the lower rate of transpiration and (b) the smaller size of hardened plants. This accounts for the fact that hardened plants can be transplanted to the field with less wilting.

The rate of water loss from hardened cabbage leaves dried in an oven at 60°C. is much less than that from leaves of tender plants. In tomato, the rate of drying is only slightly less in hardened than

in non-hardened plants. Comparing the rate of water-loss from tomato and cabbage leaves, it is found that hardened tomatoes lose water somewhat faster than tender cabbage leaves.

The lesser amount of water lost by ice formation, the lower rate of transpiration and the slower rate of water loss upon drying in hardened cabbage plants, may be explained by the hypothesis that hardening develops an increased water-retaining capacity. The water-retaining power of plant cells is due to: (a) Osmotic concentration (b) Imbibition, and may be increased by means of either or both of these factors.

Osmotic concentration of plant cells may be increased by:

(1) Decreasing the total water content.

(2) Increasing the amount of osmotically active sap solutes.

(3) Decreasing the amount of free water or conversely, by increasing the amount of unfree water held by colloidal adsorption.

Osmotic concentration as measured by the lowering of the freezing point has been found to increase on hardening plants, varying inversely with the water content. Both reducing and non-reducing sugars increase with hardening. Sugars are found to increase more in cabbage and lettuce than in tomato. The increased sugar is not sufficient to account for much difference in the freezing point depression or in the amount of water remaining unfrozen several degrees below the freezing point. The chief factor in increasing osmotic concentration in plants is considered to be the decrease in amount of free water, hence the observed increase in osmotic concentration would be a secondary result of the hardening process.

The power of imbibition possessed by plant cells may be increased by:

(1) Decreasing the total water content (or increasing the percent of dry matter).

(2) Increasing the amount of hydrophilous colloids in the protoplasm.

(3) Increasing the water-retaining power of such colloids by slight increase in acidity, etc.

Decreased water content accompanies a condition of greater cold resistance in plants. During the hardening process, the percentage of dry matter increases rapidly for a few days, and more slowly thereafter. The total pentosan content is greater in hardened than in tender plants, regardless of the kind of hardening treatment. The pentosan content of cabbage plants exposed to low temperatures in an open coldframe during March increases rapidly the first five

days and more slowly thereafter. The pentosan content of cabbage, kale and celery plants growing in the open garden increases as the weather becomes colder during the fall. In cabbage, kale and lettuce plants possessing potential hardiness, the fraction of the pentosan content soluble in hot water is larger than in tomato, eggplant and sweet potato, which do not possess potential hardiness. The hot water-soluble pentosan content is thought to represent more nearly the amount of pentosans in the protoplasm and these might function more specifically as water-retaining material. In the group of plants susceptible of considerable hardening to cold the increase in total pentosan content upon hardening is largely an increase in the hot water-soluble fraction, while in the tomato the hot water-soluble fraction does not increase upon subjecting the plants to hardening treatments.

CONCLUSIONS.

The experimental data show that the hardening process in plants is accompanied by a marked increase in water retaining power, and that this water retaining power is due chiefly to the imbibitional forces of the cell. The amount of water frozen in hardy plants is less than in tender plants and cells of hardy plants actually retain a larger amount of unfrozen water than those of tender plants.

It is believed that cold resistance in plants is due to the increased water-retaining power of the cells, which enables them upon freezing to retain a larger proportion of their moisture content in the unfrozen condition.

The increased water-retaining power of hardened plants is associated with the following changes: (a) decreased moisture content, (b) increased amount of hydrophilous colloids, such as pentosans, (c) increased water-retaining power of such cell colloids because of a slight increase in acidity or other internal changes, (d) increased amount of osmotically active substances as soluble sugars. The last factor probably is important only in plants hardened by prolonged exposure to cold; the first three factors mentioned may become operative in a very short time, when the activity of the plant is limited by any factor. Perhaps the same changes which increase the water-retaining power also favor greater stability of the protoplasm.

The marked parallelism between pentosan content and hardiness indicates a causal relationship. However, pentosan content alone is not to be taken as an absolute index of cold resistance, since several

factors may affect the functioning of pentosans as water-retaining substances. Salt content, acidity, hydrogen-ion concentration, sugar, moisture, protoplasmic colloids other than pentosans and perhaps, other factors constitute a varying complex which may influence water-retaining power and hardiness.

The differential reactions, when subjected to hardening treatments, of plants possessing potential hardiness as the cabbage and of plants lacking it as the tomato, indicate that the fundamental difference between hardy and tender species lies in their ability to initiate changes whereby the stability and water-retaining power of the protoplasm and consequently hardiness are increased. Hardy species and varieties of plants possess the ability to initiate such changes to a greater or less great degree, while tender species possess it to a very slight degree or not at all.

APPLICATIONS.

In view of the connection between cell water retaining power and hardiness which has been found and the correlation between soluble pentosan content and hardiness, it seems that problems dealing with cold resistance of vegetables, cereals, fruits and shrubs may be attacked from a new angle.

Furthermore, the association of water-retaining power of cells with their content of a specific material or group of materials, such as pentosans, may be important in the study of moisture relations and water movement in plants. Moreover it may lead to a better understanding of the cause and prevention of a group of physiological plant diseases usually associated with excessive water loss, such as Tipburn of potato and lettuce, and Blossom End Rot of tomato. Selection of plants for high soluble pentosan content may be helpful to the breeder of cold-resistant, drought-resistant, or disease-resistant varieties of crop-plants.

The changes of the food value of fruits and vegetables subjected to long storage may be significant, since it seems that in living plant tissues, exposed to water deficit or to cold the hexosan carbohydrates are converted into pentosans, which have a much lower coefficient of digestibility. However, the use of such vegetables as have a high water-retaining power may be important dietetically in the alleviation of certain digestive disorders.

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PLATE 1.—EFFECT OF EXPOSURE IN OPEN FRAMES ON COLD RESISTANCE.

A. Coldframe hardened vs. greenhouse plants frozen at -4° C. for 2½ hours. Nov. 17, 1919.

B. Cabbage plants after freezing at -8° C. for 2½ hours, March 28, 1921.
 (1) Hardened in coldframe two weeks. Lower leaves broken off for samples.
 (2) Non-hardened greenhouse plant.

Plate 2.—Effect of Variation in Soil Moisture on Cold Resistance of Cabbage.

A. Plants grown in greenhouse with varying supply of water; after freezing at –4°C. for 2½ hours. Nov. 17, 1919. (1) Dry grown (2) Medium dry (3) Wet grown.

B. (1) Medium-dry-grown greenhouse cabbage plants.
(2) Medium wet grown greenhouse cabbage plants after freezing at –4°C. for 30 minutes, March 28, 1921.

C. After freezing at –4°C. for 30 minutes, March 28, 1921.
(1) Watered heavily until one week before this test, thereafter wilted slightly for five days.
(2) Plant from same batch as (1) but not subjected to preliminary wilting.

PLATE 3.—EFFECT OF VARYING SOIL MOISTURE ON HARDINESS OF TOMATO.

A. Greenhouse tomato plants after freezing at −2°C. for 2 hours, Sept. 29, 1919.

(1) Dry-grown (2) Wet-grown.

B. Greenhouse tomato plants after freezing at −2.25°C. for 2¼ hours, Sept. 22, 1921.

(1) Dry-grown (2) Medium-dry-grown (3) Wet-grown

Plate 4—.Effect of Watering Plants Grown in Sand in Greenhouse With M/10 Salt Solutions.

A. After freezing at −6°C. for 30 minutes.
(1) NaCl (2) KCl (3) $NaNO_3$ (4) Tap water

B. After freezing at −3°C. for 30 minutes
(1) NaCl, (2) KCl. (3) $NaNO_3$ (4) Tap water.

PLATE 5.—EFFECT OF WATERING CABBAGE PLANTS GROWN IN GREENHOUSE WITH M/10 SALT SOLUTIONS,

A. Grown in compost soil and watered with:
(1) NaCl (2) KCl (3) $NaNO_3$ (4) Tap water.
After freezing at -6°C. for 30 minutes.

B. Grown in Compost soil plus rotten manure, watered with:
(1) NaCl (2) KCl (3) $NaNO_3$ (4) Tap water.
After freezing at -6°C. for 30 minutes.

PLATE 6.—RELATIVE WILTING OF HARDENED AND TENDER CABBAGE PLANTS.

A. Cabbage plants from transpiration experiment No. 4 after 5 hours of exposure to high transpiration conditions.
   (1) Greenhouse plant, watered with M/10 NaCl, hardy.
   (2) Greenhouse plant, watered sparingly with tap water, hardy.
   (3) Hardened in coldframe 5 days, hardy.
   (4) Greenhouse plant watered heavily, tender.

B. Coldframe hardened cabbage plants one day after transplanting to field, March 27, 1918, weather fair, warm, dry.

C. Greenhouse non-hardened plants, handled otherwise the same as those in B.

PLATE 7.—TENDER CABBAGE PLANT FROM GREENHOUSE FROZEN AT –5°C. FOR 30 MINUTES. MARCH 31, 1921.

Droplets of water exuding from stem and petioles upon thawing. The leaves were covered with a film of smaller droplets.

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

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EXPERIMENTS IN FIELD PLOT TECHNIC FOR THE PRELIMINARY DETERMINATION OF COMPARATIVE YIELDS IN THE SMALL GRAINS

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TABLES

EXPERIMENTS IN FIELD PLOT TECHNIC FOR THE PRELIMINARY DETERMINATION OF COMPARATIVE YIELDS IN THE SMALL GRAINS*

L. J. Stadler

During recent years the investigation of the reliability of field experiments has become an important phase of agronomic research. Field experiments as ordinarily conducted have been shown to be affected by many gross errors. In the light of these investigations it has become apparent that the results of many of the older experiments are inconclusive or even misleading. Various expedients have been suggested for counteracting experimental error. Some of these have been quite successful, while others have probably done more harm than good.

The pioneer investigations in this field have been of great value in directing attention to the important sources of error and in suggesting possible means for their control. Doubtless at the present time most of the major sources of error are recognized. But the true extent of the errors and the actual practical value of the methods of counteracting them can be determined only by numerous investigations of experimental methods under different conditions.

The present paper is concerned with experimental error and field plot technic in preliminary variety and strain tests with the small grains. The same type of test is extensively used in small grain improvement, not only in the preliminary testing of varieties, but also in the comparison of strains and selections. Although the small plot test is particularly subject to errors of certain sorts, it has a decided advantage over tests in larger plots in the possibility of extensive replication, which is probably the greatest single factor in the reduction of experimental error. It should be possible, consequently, to obtain extremely accurate results in small plot tests without the use of large experimental areas, when the errors peculiar to the small plot are understood and controlled.

*Also submitted as a thesis in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

THE PROBLEM.

At present the type of plot most commonly used for the preliminary testing of small grain varieties and strains is probably the "rod-row." The methods of conducting rod-row tests described by Love and Craig[9] may be considered typical. The varieties or strains are sown by hand in rows one foot apart, usually opened and covered with a wheel hoe or similar implement. The seed for each row is weighed out in a quantity equivalent to ordinary rates of seeding in field practice. In harvesting, six inches or a foot at the end of the row is discarded, to prevent increase in yield by reason of the more favorable space conditions at the ends of the rows. The list of varieties is repeated in several series, and the results averaged to reduce the error from plot variability. A check variety is grown in every tenth row to indicate the variability of the field.

The use of rod-row tests involves several errors, derived principally from the modified conditions under which the plants are grown. The object of the test is to discover the relative value of the strains under field conditions, and therefore any modification of field conditions which may favor some sorts more than others introduces error. The wide spacing between rows, with consequently heavier seeding in the row for any given rate of planting; the hand seeding and covering, resulting usually in slightly ridged rather than slightly furrowed rows; and the growing of different varieties in single rows, in competition with other varieties rather than with their own kind, are examples of typical conditions which may be expected to favor some varieties more than others. Consequently the best varieties in the rod-row test are not necessarily the best varieties under field culture, even when soil and seasonal variability are reduced to the minimum by replication of plots and repetition of the test through a series of seasons.

Such sources of error as those mentioned do not necessarily affect the variability of the yields of replicate plots, as Kiesselbach[6] has pointed out, and are therefore more likely to escape notice. They are systematic errors affecting the yields of replicate plots similarly. Marked superiority of Turkey wheat over Fulcaster in a variety test in Kansas does not indicate the superiority of Turkey over Fulcaster in Illinois, no matter how low plot variability in the variety test may be, because the growing conditions in Illinois are different from the growing conditions in Kansas. Similarly the superiority of Turkey wheat over Fulcaster in a rod-row test may not mean its superiority under field conditions in the same locality, because here again growing

conditions are different. The error in applying the results, though of course much less in degree, is similar in kind. And, since the rod-row test has no purpose but to indicate the relative value of the strains tested, for field conditions, any pronounced tendency to favor some varieties at the expense of others is fatal to its object.

Ordinarily, however, the rod-row test is only the first stage in variety testing, and final recommendations are based upon results of tests under conditions which approach those of field culture more closely. When the elimination of varieties in the rod-row tests is not extremely strict a considerable latitude may be allowed, and under these conditions the rod-row test has served a valuable purpose. It is of course desirable nevertheless to reduce these errors to the greatest possible extent.

Probably the most important of the errors mentioned is that arising from the competition between different varieties, in the single-row test. Obviously a variety grown in a single row between two different varieties may yield considerably more or less than the same variety grown between two rows of its own kind. Various expedients for reducing varietal competition have been suggested. Sometimes the order of varieties is changed in each series to bring together different varieties and thus tend to equalize the effects of competition; sometimes an attempt is made to grow the varieties in such order as to bring together those of similar habit, and thus to reduce the effects of competition. Probably the most effective method is to grow border rows which may be discarded, and some investigators therefore use three-row or five-row blocks, in which the outer row on each side is discarded.

The principal objection to the use of border rows in the increased area required to test the same number of strains, and the large proportion of the crop which is not harvested for yield. This is particularly true when 3-row blocks are used, since in this case two-thirds of the field is used for border protection. The border rows may be used for seed, but two-thirds of the field is of course much more than is required ordinarily for this purpose. When 5-row blocks are used the proportion of the crop harvested for yield is increased from one-third to three-fifths, though it is an increase in size of plot, with some decrease in replication, so that there may be no gain in accuracy. There is a possibility that the effect of competition on the yield of 5-row blocks may be slight enough to permit the harvesting of all five rows for yield, particularly if the varieties may be effectively arranged for the reduction of competition. At any rate, in such plots the error from competition may be expected to be much less than that in single-

row plots, since only two of the five rows are subject to competition with a different variety, and each of these is subject to such competition on only one instead of on both sides.

Another phase of the question which should not be overlooked is the effect of adding border rows on the error from soil variability. If, for example, each rod-row is to be protected from competition by two border rows, the test will require three times as large a field as the same test without the border rows. This can hardly fail to increase materially the variability of the yields of replicate plots, to an extent which will vary with the uniformity of the field concerned. The use of border rows may thus necessitate the use of an even greater number of replications for the same degree of accuracy, as far as plot variability is concerned. It is possible that 3-row plots (whether or not provided with border rows) may require less replications for a given degree of accuracy than single-row plots, on account of their larger size. It is possible also that 5-row plots, because of their size, may have an advantage over 3-row plots in reducing variability, great enough to justify in practice harvesting all five rows for yield, rather than harvesting the interior three rows and discarding the border rows.

The importance of any practice that will reduce the variability of the replicate plots is thus increased when border rows are introduced. A familiar method for this purpose is the adjustment of yields by means of distributed check plots. In following this method the yields of check plots are considered measures of the productivity of the soil, which is usually assumed to vary uniformly between them. The yields of the experimental plots are adjusted on the basis of uniform productivity of the field as a whole. Of late this method has rather lost favor among agronomists. In some cases the adjustment actually increases rather than decreases the variability of the replicate experimental plots. Check plots have not been used extensively in adjusting yields in rod-row tests, principally because of the great increase in computation necessary in adjusting the yields of such a large number of plots.

PLAN AND METHOD OF INVESTIGATION

The experiments here reported were designed to obtain information on several factors affecting the accuracy of preliminary variety and strain tests, with a view to devising, if possible, an improved technic for this important phase of crop improvement work. The data obtained bear directly on the following points:

1. The extent of error from varietal competition in border rows, and the relation of such competition to the characteristics of the varieties,
2. The relative variability of plots of 1, 3, and 5 rows, and the number of replications necessary for a given degree of precision with plots of the three sizes, and
3. The effect on variability of adjusting yields by means of check plots.

Terminology.—In this report the term plot will be used to designate an area on which a single variety or strain is grown, in comparison with other varieties or strains, in other plots. The plot may consist of one or more rows. A plot of more than one row may also be referred to as a block. The single outside rows of the block are the border rows. A single-row plot protected from competition by border rows, which are to be discarded, will be spoken of as a protected single-row plot. A protected single-row plot is therefore a 3-row plot with border rows discarded, and a protected 3-row plot is a 5-row plot with border rows discarded. The phrase "3-row plots replicated five times" will be used to refer to 3-row plots in five systematically distributed locations, not in six. The area on which a complete variety or strain test is conducted is spoken of as an experiment field, or simply a field. A group of plots including one plot of each variety or strain tested is a series. When four replications are used there are four series of plots. The group of contiguous plots from one side of the field to the other constitutes a range. The ranges are separated by alleys.

Thus the field shown in figure 1 consists of sixteen ranges, each range including twenty-nine 5-row (or protected 3-row) plots. Ninety-six varieties were tested on this field, each replicated four times. Ranges I to IV, inclusive, make up the first series, V to VIII the second, IX to XII the third, and XIII to XVI the fourth. Each of the four strips running lengthwise of the field and separated by the check plots may also be considered a series.

All yields are expressed in bushels per acre by weight, computed on the basis of 60 pounds per bushel for wheat, 48 pounds for barley,

B	CK	1	17	33	49	65	81	CK	5	21	37	53	69	85	CK	9	25	41	57	73	89	CK	13	29	45	61	77	93	CK
B	CK	2	18	34	50	66	82	CK	6	22	38	54	70	86	CK	10	26	42	58	74	90	CK	14	30	46	62	78	94	CK
B	CK	3	19	35	51	67	83	CK	7	23	39	55	71	87	CK	11	27	43	59	75	91	CK	15	31	47	63	79	95	CK
B	CK	4	20	36	52	68	84	CK	8	24	40	56	72	88	CK	12	28	44	60	76	92	CK	16	32	48	64	80	96	CK
B	CK	5	21	37	53	69	85	CK	9	25	41	57	73	89	CK	13	29	45	61	77	93	CK	1	17	33	49	65	81	CK
B	CK	6	22	38	54	70	86	CK	10	26	42	58	74	90	CK	14	30	46	62	78	94	CK	2	18	34	50	66	82	CK
B	CK	7	23	39	55	71	87	CK	11	27	43	59	75	91	CK	15	31	47	63	79	95	CK	3	19	35	51	67	83	CK
B	CK	8	24	40	56	72	88	CK	12	28	44	60	76	92	CK	16	32	48	64	80	96	CK	4	20	36	52	68	84	CK
B	CK	9	25	41	57	73	89	CK	13	29	45	61	77	93	CK	1	17	33	49	65	81	CK	5	21	37	53	69	85	CK
B	CK	10	26	42	58	74	90	CK	14	30	46	62	78	94	CK	2	18	34	50	66	82	CK	6	22	38	54	70	86	CK
B	CK	11	27	43	59	75	91	CK	15	31	47	63	79	95	CK	3	19	35	51	57	83	CK	7	23	39	55	71	87	CK
B	CK	12	28	44	60	76	92	CK	16	32	48	64	80	96	CK	4	20	36	52	68	84	CK	8	24	40	56	72	88	CK
B	CK	13	29	45	61	77	93	CK	1	17	33	49	65	81	CK	5	21	37	53	69	85	CK	9	25	41	57	73	89	CK
B	CK	14	30	46	62	78	94	CK	2	18	34	50	66	82	CK	6	22	38	54	70	86	CK	10	26	42	58	74	90	CK
B	CK	15	31	47	63	79	95	CK	3	19	35	51	67	83	CK	7	23	39	55	71	87	CK	11	27	43	59	75	91	CK
B	CK	16	32	48	64	80	96	CK	4	20	36	52	68	84	CK	8	24	40	56	72	88	CK	12	28	44	60	76	92	CK

FIGURE 1.—PLANTING PLAN OF WHEAT VARIETY TESTS 1920 AND 1921. Legend: B, border. CK, check. Numbers 1-96, planting numbers of varieties tested as given in Tables 4 and 5.

and 32 pounds for oats. The measures of variability used are the average deviation, the standard deviation, and the probable error. These were computed according to the following formulæ:

$$A.D = \frac{\Sigma d}{n},$$

$$\sigma = \sqrt{\frac{\Sigma d^2}{n}}, \text{ and}$$

$$E = \pm .6745\ \sigma.$$

in which A.D. = average deviation, σ=standard deviation, E = probable error (of a single determination), d = the deviation of a single variate from the mean, and n = the number of variates. The correlation coefficient r was determined by the formula

$$r = \left(\frac{\Sigma (d_x d_y)}{n}\right)\left(\frac{1}{\sigma_x \sigma_y}\right)$$

and the probable error of the correlation coefficient E_r by the formula

$$E_r = \pm \frac{.6745\ (1 - r^2)}{\sqrt{n}}$$

The tests reported are of two kinds, variety tests and strain tests. The variety tests were comparisons of commercial varieties, most of which were taxonomically distinct. A number of pure line selections were included in the wheat variety tests. The strain tests were comparisons of a considerable number of commercial lots of the same variety obtained from different sources. These strains, so-called for convenience, are not, except in a very few cases, pure lines. Some of them are possibly identical, and all the strains of any one variety are of course very similar, since they are taxonomically the same.

Procedure.—In the seasons of 1919, 1920, 1921, tests of varieties and strains of oats, barley, and wheat were conducted in blocks consisting of five rows ten inches apart and usually 18 feet long. From 24 to 96 varieties were included in each test, and from three to six (usually four) replications were used. The planting order in each case was designed on a plan similar to that illustrated in figure 1. It will be noted that the check plots were in continuous strips, that each variety was represented in each quarter of the field, whether divided from east to west or from north to south, and that in all four series each variety occupied the same position with relation to the check plots, and had the same varieties adjoining it on either side.

The rows in some cases ran east and west, and in some cases north and south.

All these plots were seeded with a 5-row nursery drill, built from plans furnished by Professor T. A. Kiesselbach of the Nebraska Station. This is a hoe drill designed for rapid and thorough cleaning between plots. Photographs of it have been published in reports of earlier work on field plot technic at the Nebraska Station (Montgomery[14] page 57, and Kiesselbach [6] page 16). Its use resulted in uniform seeding and covering and accurate spacing between rows, with a close approach to ordinary field conditions in the state in which the field was left after seeding. Each field was seeded in a single day.

All plots were harvested by hand with sickles, a foot at each end of each row discarded, and the remainder (usually 16 feet) tied in a bundle and hung in a ventilated shed to dry. In 1919 and 1920 each row was bundled and threshed separately; in 1921 the border rows of each 5-row block were bundled separately and the three interior rows bundled together. Yields were determined by weighing in grams at the time of threshing. All final yields were converted to bushels per acre and are so expressed.

Work of 1919.—In 1919 tests were conducted with barley and oats. Thirty varieties of barley were grown, each in 3 replicate plots. The test comprised three ranges of 185 rows each, including 21 check plots, or one in every sixth plot. The barley was drilled at the rate of eight pecks per acre, on March 21, in rows running north and south. The rows were 14 feet long and 10 inches apart. They were cut to 12 feet in harvesting. The planting plan is shown in figure 2. Conditions

CK	1	2	3	4	5	CK	6	7	8	9	10	CK	11	12	13	14	15	CK	16	17	18	19	20	CK	21	22	23	24	25	CK	26	27	28	29	30	CK	B
CK	21	22	23	24	25	CK	26	27	28	29	30	CK	1	2	3	4	5	CK	6	7	8	9	10	CK	11	12	13	14	15	CK	16	17	18	19	20	CK	B
CK	11	12	13	14	15	CK	16	17	18	19	20	CK	21	22	23	24	25	CK	26	27	28	29	30	CK	1	2	3	4	5	CK	6	7	8	9	10	CK	B

FIGURE 2.—PLANTING PLAN OF BARLEY VARIETY TEST 1919. Legend: B, border. CK, check. Numbers 1-30, planting numbers of varieties tested, as given in Table 1.

were fairly favorable, and the yields of the adapted varieties were slightly higher than the average obtained under the conditions at Columbia. Two varieties, Italian and Australian White, gave extremely low yields and were excluded. Another, Sandrel, was represented only in two series, and was also excluded. The yields of the remain-

ing 27 varieties are shown in Table 1. The planting numbers given in this table correspond to those shown in the diagram of the field (figure 2.)

Table 1.—Yields of Barley Varieties.
In Bushels per Acre. 1919.

Planting number	Variety	Average Yield 3 interior rows	5 rows
1	Hanna 906	12.55	12.57
2	Steigum 907	19.90	19.65
3	Luth 908	23.65	23.40
4	Eagle 913	20.40	20.13
5	Italian 914*	6.70	6.57
6	Servian 915	19.85	19.86
7	Odessa 916	13.75	13.41
8	Lion 923	21.75	22.14
9	Australian White 925*	1.45	1.74
10	Horn 926	21.25	21.54
11	Odessa 927	20.80	19.53
12	Summit 929	23.05	24.03
13	Mariout 932	18.75	18.15
14	Odessa 934	10.30	9.84
15	Peruvian 935	22.25	20.55
16	Trebi 936	30.90	30.96
17	Sandrel 937*	35.90	33.48
18	Oderbrucker 940	23.35	23.79
19	Frankish 953	22.50	22.05
20	Manchuria 956	30.80	30.03
21	Oderbrucker 957	29.45	29.52
22	Manchuria x Champion of Vermont 959	18.30	17.49
23	Luth 972	25.05	26.28
24	Red River 973	27.25	28.14
25	Featherston 1118	28.25	27.00
26	Featherston 1119	25.80	25.83
27	Featherston 1120	34.35	35.49
28	Hanna x Champion of Vermont 1121	13.75	13.92
29	Manchuria 1125	20.35	20.94
30	Malting 1129	17.25	16.44
	Mean	22.06	21.95

Forty varieties of oats were compared in 1919, but only 24 of these could be replicated 4 times and the remaining 16 were duplicated. The planting plan was therefore arranged as for 32 varieties, and these 16 varieties grown in two plots each in place of eight varieties

*Italian 914 and Australian White 925 were omitted from all computations because of their extremely low yields, and Sandrel 937 because omitted in the third series.

CK	1	2	3	4	5	6	7	8	CK	9	10	11	12	13	14	15	16	CK	17	18	19	20	21	22	23	24	CK	25	26	27	28	29	30	31	32	CK	B
CK	33	34	35	36	37	38	39	40	CK	1	2	3	4	5	6	7	8	CK	9	10	11	12	13	14	15	16	CK	17	18	19	20	21	22	23	24	CK	B
CK	17	18	19	20	21	22	23	24	CK	25	26	27	28	29	30	31	32	CK	1	2	3	4	5	6	7	8	CK	9	10	11	12	13	14	15	16	CK	B
CK	9	10	11	12	13	14	15	16	CK	17	18	19	20	21	22	23	24	CK	33	34	35	36	37	38	39	40	CK	1	2	3	4	5	6	7	8	CK	B
CK									S	E	E	D		M	U	L	T	I	P	L	I	C	A	T	I	O	N									CK	B
CK	1	2	3	4	5	CK	6	7	8	9	10	CK	11	12	13	14	15	CK	1	2	3	4	5	CK	6	7	8	9	10	CK	11	12	13	14	15	CK	B
CK	11	12	13	14	15	CK	1	2	3	4	5	CK	6	7	8	9	10	CK	11	12	13	14	15	CK	1	2	3	4	5	CK	6	X	X	9	10	CK	B
CK	6	7	8	9	10	CK	11	12	13	14	15	CK	1	2	3	4	5	CK	6	7	8	9	10	CK	11	12	13	14	15	CK	X	2	X	X	X	CK	B

FIGURE 3.—PLANTING PLAN OF OATS VARIETY AND STRAIN TESTS 1919. Legend: B, border. CK, check. Numbers 1-40 in first four ranges, planting numbers of oats varieties, as given in Table 2. Numbers 1-15 in last three ranges, planting numbers of oats strains, as given in Table 3. X, test plots planted to check variety because of insufficient supply of seed.

TABLE 2.—YIELDS OF OATS VARIETIES.
In Bushels per Acre. 1919.

Planting number	Variety	Average yield in interior rows Four series	Three series
1	A. Sterilis nigra	30.0	31.7
2	Black Mesdag	44.2	44.7
3	C. I. 602	35.4	38.1
4	C. I. 603	53.9	55.1
5	C. I. 620	13.1	14.1
6	Early Champion	55.5	53.9
7	Early Gothland	54.1	52.8
8	Garton 473	30.6	31.7
9	Garton 585	21.7	23.0
10	Golden Giant	42.0	44.9
11	Irish Victor	69.6	70.2
12	Japan Selection	47.9	50.9
13	June	43.1	44.5
14	Kherson Selection	67.2	63.1
15	Fulghum 042	60.9	57.1
16	Lincoln	51.5	50.3
17	Monarch	56.0	53.4
18	North Finnish	51.0	49.5
19	Scottish Chief	59.3	60.1
20	Sparrow bill (Missouri)	39.8	41.3
21	Sparrow bill (Cornell)	42.3	45.7
22	Tobolsk 1	52.6	57.3
23	Tobolsk 2	46.1	51.9
24	White Tartar	49.7	50.3
	Mean	46.6	47.3

in four plots each, as shown in figure 3. The rows were 14 feet long and were cut to 12 feet in harvesting. This is a convenient size of plot for oats tests with 10 inches distance between rows, when the border rows are discarded, since the total yield of three rows in grams, divided by 10, gives the yield in bushels per acre. The oats were planted at the rate of 10 pecks per acre, on March 18, in rows running north and south. The season was favorable and a good yield of the better varieties was obtained. The yields of the 24 varieties replicated four times are shown in Table 2.

The oats strain test was conducted on the same field, as shown in figure 3, directly south of the oats variety test. In planting, these two tests were handled as one; and the rate, date, and method of planting were the same. The strains tested were 15 strains of oats obtained under the name Red Rustproof from various experiment stations and seedsmen. Three of these strains, 0121, 0124, and 0127, were not true to name, but the remainder were taxonomically Red Rustproof oats, as described by Etheridge[2]. The oats strains were tested in six series, with check plots in every sixth plot. The line of check plots on the west, however, gave abnormally low yields, probably because they were located partly on a dead furrow at the edge of the experiment field. On account of shortage of seed some of the varieties could not be planted in the last series. The first and last series were therefore dis-

TABLE 3.—YIELDS OF OATS STRAINS (RED RUSTPROOF).
In Bushels per Acre. 1919.

Planting number	Accession number	Average yield 3 interior Rows	5 Rows
1	0119	49.58	49.41
2	0120	45.83	44.51
3	0121*	49.43	53.01
4	0122	47.85	49.59
5	0123	53.55	53.47
6	0125	50.18	49.19
7	0126	44.85	45.81
8	0127*	38.55	36.67
9	0124*	63.90	67.46
10	0133	48.00	46.49
11	0128	53.55	53.15
12	0129	49.35	49.01
13	0130	52.73	51.89
14	0131	48.60	47.84
15	0132	55.13	55.44
	Mean	50.07	50.20

*Not taxonomically Red Rustproof.

carded. The average yields of the 15 strains in the four remaining series are shown in Table 3.

Work of 1920.—Wheat varieties were grown in 5-row blocks in 1919-20. Ninety-six varieties were included in the test, four replications being used. Fultz wheat was grown as a check in every sixth plot. The rows were 18 feet long and were cut to 16 feet in harvesting. The direction of the rows was east and west. The planting plan is shown in figure 1. The wheat was sown October 15, at the rate of 6 pecks per acre. There was considerable winter injury in the plots and the condition of the wheat in early spring was rather poor. The yields obtained are shown in Table 4.

TABLE 4.—YIELDS OF WHEAT VARIETIES.
In Bushels per Acre 1920.

Planting number	Variety	Average yield 3 Interior Rows	Average yield 5 Rows
1	Beechwood Hybrid No. 12	10.8	11.1
2	Beechwood Hybrid No. 81	12.8	14.1
3	Beechwood Hybrid No. 85	12.5	12.7
4	Beechwood Hybrid No. 87	14.2	13.7
5	Beechwood Hybrid No. 202	11.9	12.5
6	Beechwood Hybrid No. 207	13.2	13.6
7	C. I. 3808	16.2	16.6
8	C. I. 3846	14.2	15.6
9	C. I. 3972	14.7	15.6
10	C. I. 3980	16.4	17.5
11	C. I. 3988	16.7	17.0
12	C. I. 4004	14.3	14.0
13	Common Rye	17.3	18.5
14	Dawson's Golden Chaff	13.0	12.3
15	Deitz	15.1	14.6
16	Early Ripe	12.2	12.6
17	Early Ripe No. 26	13.2	14.0
18	Early Red Clawson	9.9	9.5
19	Farmer's Friend	18.8	19.9
20	Fulcaster	14.4	15.3
21	Fultz (Archias)	12.2	13.0
22	Gold Coin	11.7	12.2
23	Greene County	15.6	15.1
24	Harvest King No. 7	13.4	14.2
25	Harvest Queen	9.6	9.8
26	Hickman	7.8	8.2
27	Illini Chief	17.5	18.7
28	Jones Climax	19.1	20.7
29	Kanred	21.0	22.7
30	Kessinger	18.0	19.3
31	Kharkov	18.9	20.1
32	Leap's Prolific	14.2	14.8
33	Mediterranean No. 8	9.1	9.5
34	Michigan Amber	10.7	11.3
35	Michigan Amber (Indiana)	17.0	17.9
36	Michigan Amber No. 7	10.5	10.8
37	Michigan Amber No. 12	9.3	9.3
38	Michigan Wonder	10.9	11.1
39	Michigan Wonder No. 4	12.4	12.7
40	Michigan Wonder No. 8	10.8	11.0
41	Michigan Wonder No. 21	8.2	8.7
42	Michigan Wonder No. 53	8.5	9.6
43	Michigan Wonder No. 54	11.3	10.7
44	Michigan Wonder No. 83	13.6	13.7
45	Michigan Wonder No. 96	9.7	9.7
46	Michigan Wonder No. 103	9.7	9.1
47	Michigan Wonder No. 116	16.4	15.8
48	Michigan Wonder No. 130	14.3	14.2
49	Michigan Wonder No. 140	12.3	12.7
50	Michigan Wonder No. 141	10.7	10.3
51	Michigan Wonder No. 155	10.1	9.8
52	Michigan Wonder No. 209	12.1	12.5
53	Michigan Wonder No. 211	9.9	9.9
54	Michigan Wonder No. 221	11.0	11.1
55	New York 123-32	17.2	17.5
56	Niagara	13.8	13.5
57	Nigger	11.8	11.8
58	Old Ironclad	12.5	13.2
59	Poole	10.5	10.7
60	Poole No. 3	11.7	11.0
61	Poole B-3	12.5	13.3
62	Portage	15.9	17.3
63	Pride of Indiana	14.2	14.4
64	Pride of Genessee	15.7	18.1
65	Reliable	12.6	12.9
66	Red Cross	13.1	13.1
67	Red May	14.8	14.8
68	Red Rock (Indiana)	18.7	19.7
69	Red Rock (Michigan)	7.5	6.8
70	Red Wave	12.9	12.7
71	Rochester Red	12.7	12.9
72	Rosen Rye	20.7	24.0
73	S. P. I. 11616	10.3	10.9
74	S. P. I. 26012	13.4	12.9
75	S. P. I. 26013	15.2	15.5
76	S. P. I. 26014	17.5	18.8
77	S. P. I. 26015	13.2	13.4
78	S. P. I. 26017	13.4	13.5
79	S. P. I. 26018	13.6	13.6
80	S. P. I. 26019	11.6	11.6
81	S. P. I. 26022	10.6	10.1
82	S. P. I. 26023	9.1	8.5
83	S. P. I. 26025	12.3	13.1
84	S. P. I. 26029	15.4	15.6
85	S. P. I. 26085	13.2	13.3
86	Treadwell	12.7	12.8
87	Valley	12.4	12.1
88	Velvet Chaff No. 2	14.1	12.8
89	Velvet Chaff No. 8	9.0	9.3
90	Ziegler's Fly Proof	10.9	11.7
91	13D-4a	14.1	13.9
92	37a-4	14.6	14.7
93	Fulcaster (Co-op)	17.4	18.5
94	Fultz (Co-op)	15.2	15.9
95	Kanred (Co-op)	19.1	20.6
96	Poole (Co-op)	19.4	21.0
	Mean	13.4	13.8

TABLE 5.—YIELDS OF WHEAT VARIETIES.
In Bushels per Acre. 1921.

Planting Number	Variety	Average Yield: Four series, 3 interior rows	Four series, 5 rows	Three series, 3 interior rows	Three series, 5 rows
1	Beechwood Hybrid No. 12	16.7	16.8	17.6	17.2
2	C. I. 3808	10.7	10.4	10.3	9.4
3	C. I. 3846	10.9	11.4	10.7	11.4
4	C. I. 3972	11.2	11.8	10.7	10.9
5	C. I. 3980	11.6	11.5	11.0	11.2
6	C. I. 4004	13.1	13.4	13.2	13.1
7	Common Rye	17.0	20.5	16.3	20.0
8	Dietz	14.8	15.8	14.7	15.3
9	Defiance	14.0	15.1	14.4	15.5
10	Early Ripe	16.7	17.6	15.9	17.0
11	Early Ripe No. 26	15.0	15.4	15.5	15.9
12	Early Red Clawson	14.6	15.2	15.9	16.5
13	Farmers' Friend	19.4	19.5	19.1	19.2
14	Fulcaster	18.2	18.7	18.6	19.0
15	Fulcaster 1-y	17.8	18.0	18.4	18.4
16	Fulcaster 8-y	18.4	19.7	18.6	19.8
17	Fulcaster (Co-op)	17.1	17.7	18.0	18.8
18	Fulcaster (Holmes)	15.3	14.8	15.7	14.8
19	Fulcaster (Blazier)	17.0	17.7	16.8	17.3
20	Fulcaster (Cowles)	15.9	15.7	15.6	15.1
21	Fulcaster (Outl)	18.0	18.0	17.8	18.4
22	Fultz (Co-op)	14.8	15.1	15.2	14.9
23	Fultz (Bayer)	12.2	12.1	12.0	11.9
24	Fultz (Gale)	13.1	13.5	13.0	13.2
25	Fultz (Check)	14.2	13.8	14.2	14.0
26	Harvest Queen	13.5	13.8	13.3	13.5
27	Illini Chief	17.1	17.2	16.6	16.6
28	Jones Climax	14.3	14.2	13.7	13.6
29	Kanred	16.2	15.3	16.5	15.2
30	Kanred (Co-op)	13.9	13.6	13.4	13.1
31	Kessinger	14.6	14.4	14.7	14.3
32	Kharkov	10.9	10.2	9.8	9.0
33	Leap Prolific	14.9	13.5	14.7	13.3
34	Mediterranean No. 30	16.5	16.2	16.5	16.6
35	Mediterranean No. 31	16.1	16.3	15.8	16.1
36	Michigan Amber	14.6	14.5	14.8	14.4
37	Michigan Amber No. 7	15.0	14.7	15.5	15.0
38	Michigan Amber No. 12	16.6	16.5	17.1	16.8
39	Michigan Amber (Indiana)	14.9	14.6	14.5	14.3
40	Michigan Wonder	16.1	15.7	15.6	15.1
41	Michigan Wonder No. 4	17.6	17.8	17.9	18.2
42	Michigan Wonder No. 8	18.5	18.8	17.7	18.1
43	Michigan Wonder No. 21	17.7	19.1	17.3	18.8
44	Michigan Wonder No. 53	18.4	18.6	17.8	18.0
45	Michigan Wonder No. 54	18.4	19.0	18.9	19.6
46	Michigan Wonder No. 83	16.2	16.5	16.7	17.1
47	Michigan Wonder No. 96	14.7	15.2	14.6	15.4
48	Michigan Wonder No. 103	15.5	15.8	15.5	15.9
49	Michigan Wonder No. 116	16.4	17.9	17.0	18.4
50	Michigan Wonder No. 130	14.5	15.1	14.6	15.1
51	Michigan Wonder No. 140	14.6	14.3	14.8	14.5
52	Michigan Wonder No. 141	17.4	16.4	16.9	15.4
53	Michigan Wonder No. 155	16.3	16.2	15.8	15.7
54	Michigan Wonder No. 209	17.6	18.3	17.7	18.3
55	Michigan Wonder No. 211	18.1	18.7	18.1	18.3
56	Michigan Wonder No. 221	19.1	18.6	18.6	18.0
57	New York 123-32	19.3	19.3	18.4	18.7
58	Nigger	13.6	12.8	12.6	12.1
59	Old Ironclad	10.9	10.6	10.4	10.2
60	Poole	16.9	16.8	15.7	15.8
61	Poole B3	13.2	13.2	12.3	12.2
62	Poole (Co-op)	14.8	14.0	14.9	13.7
63	Poole (Scott)	14.3	13.4	14.3	13.4
64	Poole (Corder)	14.5	14.7	14.6	14.4
65	Poole (Sel)	15.3	14.5	14.9	14.0
66	Portage	15.3	15.4	15.4	15.6
67	Pride of Indiana	15.4	15.5	15.5	15.4
68	Red Hussar	14.3	14.0	13.8	13.4
69	Red Wave (Chesterfield)	15.2	15.3	15.8	16.2
70	Red Wave (McCauley)	13.0	12.6	13.3	12.9
71	Red Rock (Indiana)	15.6	15.5	15.0	14.9
72	Red Rock (Michigan)	16.4	16.0	16.2	15.8
73	Rochester Red	17.6	17.0	17.2	16.9
74	S. P. I. 26017	14.8	14.5	15.1	14.5
75	S. P. I. 26018	12.8	12.7	12.4	12.3
76	S. P. I. 26019	12.7	13.0	13.1	13.4
77	S. P. I. 25984	13.3	12.8	12.8	12.2
78	Beechwood Hybrid No. 207	14.9	14.7	15.1	15.1
79	S. P. I. 26022	11.7	11.1	11.7	10.9
80	S. P. I. 26023	12.6	11.7	11.6	10.6
81	S. P. I. 26025	13.9	14.3	12.8	13.2
82	S. P. I. 26029	15.7	15.1	15.5	14.8
83	S. P. I. 26085	12.6	12.2	12.0	11.6
84	Rosen Rye	17.9	19.9	17.7	19.6
85	Texas	15.5	15.4	15.5	15.5
86	Turkey	16.9	17.4	17.2	17.2
87	Turkey No. 24	15.0	14.9	15.2	15.0
88	Turkey (Kansas)	12.9	12.9	14.1	14.2
89	Velvet Chaff	13.4	14.6	14.5	15.5
90	Velvet Chaff No. 2	18.9	20.2	20.1	21.1
91	Velvet Chaff No. 8	16.8	17.5	17.4	18.1
92	Ziegler Fly-proof	17.2	18.1	18.7	19.4
93	Poole No. 3	16.5	17.7	16.3	17.5
94	18B-4	17.0	17.7	17.6	18.4
95	Mediterranean No. 17	18.4	18.7	18.6	18.7
96	34B-2a	19.1	21.0	20.0	21.8
	Mean	15.4	15.6	15.4	15.5

Work of 1921.—In 1920-21 ninety-six varieties of wheat were again tested by this method. Many of the varieties were the same as those tested in the preceding year, about 20 varieties being eliminated and a corresponding number added. The planting plan was the same as that of the preceding season. Poole wheat was used as a check variety. The wheat was drilled at the rate of 5 pecks per acre, October 6, in rows running east and west. The season was favorable, but yields were reduced by the very rapid ripening of the wheat caused by the hot dry weather in the second and third weeks of June. The yields are shown in Table 5.

TABLE 6.—YIELDS OF WHEAT VARIETIES AND MIXTURES
In Bushels per Acre. 1921.

Planting number	Variety	Average yield 3 Interior Rows	5 Rows
1	Fulcaster	17.3	18.6
2	Harvest Queen	14.2	14.5
3	Mixture No. 1 (1, 2, 4, 5)	15.9	16.2
4	Michigan Wonder	16.8	17.8
5	Nigger	10.8	10.8
6	Michigan Wonder No. 21	19.8	20.8
7	Michigan Wonder No. 54	18.9	19.3
8	Mixture No. 2 (6, 7, 9, 10)	20.8	21.3
9	Michigan Wonder No. 96	18.5	18.9
10	Michigan Wonder No. 209	21.7	22.6
11	Beechwood Hybrid No. 12	17.4	18.8
12	Beechwood Hybrid No. 85	16.5	17.3
13	Mixture No. 3 (11, 12, 14, 15)	17.6	18.4
14	Beechwood Hybrid No. 87	19.9	19.9
15	Beechwood Hybrid No. 207	17.4	17.9
16	Michigan Wonder No. 221	18.6	20.3
17	Kanred	13.6	13.8
18	Mixture No. 4 (16, 17, 19, 20)	17.8	18.0
19	New York 123-32	19.6	19.7
20	Red Rock	17.6	17.4
21	Red Hussar	16.3	17.8
22	Turkey (Kansas)	10.8	10.5
23	Mixture No. 5 (21, 22, 24, 25)	15.7	15.9
24	Michigan Amber	19.2	19.6
25	Nigger	14.1	13.4
26	Fulcaster (Co-op)	20.4	21.2
27	Fulcaster (Outl)	20.1	20.6
28	Mixture No. 6 (26, 27, 29, 30)	20.1	21.0
29	Fulcaster (Blazier)	20.6	21.5
30	Fulcaster (Cowles)	20.6	20.6
	Mean	17.6	18.2

On another field in 1921, a test of mixtures of varieties and strains of wheat in comparison with their pure constituents was conducted. Each mixture was made up of four varieties or strains, in equal quantities of seed by weight. The composition of the mixtures and the yields obtained are shown in Table 6. The planting plan is shown in figure 4. This wheat was drilled at the rate of 5 pecks per

B	CK	1	2	3	4	5	CK	26	27	28	29	30	CK	16	17	18	19	20	CK	11	12	13	14	15	CK	B
B	CK	6	7	8	9	10	CK	1	2	3	4	5	CK	21	22	23	24	25	CK	16	17	18	19	20	CK	B
B	CK	11	12	13	14	15	CK	6	7	8	9	10	CK	26	27	28	29	30	CK	21	22	23	24	25	CK	B
B	CK	16	17	18	19	20	CK	11	12	13	14	15	CK	1	2	3	4	5	CK	26	27	28	29	30	CK	B
B	CK	21	22	23	24	25	CK	16	17	18	19	20	CK	6	7	8	9	10	CK	1	2	3	4	5	CK	B
B	CK	26	27	28	29	30	CK	21	22	23	24	25	CK	11	12	13	14	15	CK	6	7	8	9	10	CK	B

FIGURE 4.—PLANTING PLAN OF WHEAT MIXTURE TEST 1921. Legend: B, border. CK, check. Numbers 1-30, planting numbers of varieties and mixtures tested, as given in Table 6.

acre in rows running north and south, on October 8, 1920. This test will be referred to as the wheat mixture test.

In 1921 tests of oats varieties and of oats strains were also conducted in 5-row blocks. Thirty-two strains of Red Rustproof, including many of those tested in 1919 and a number of others, and 32 strains of Kherson oats, obtained in the same way, were included in the oats strain test. The Kherson and Red Rustproof strains were arranged alternately, and both Kherson and Red Rustproof checks were grown, as shown in figure 5. The test of these 64 strains, in four series, occupied 16 ranges. The next eight ranges on the same plot were used for an oats variety test in which 32 varieties of oats were compared, each in four replicate plots. In this part of the field the Kherson and Red Rustproof check plots were continued. There are thus available the yields of 120 plots each of Kherson and Red Rustproof oats, or five strips of 24 plots of each arranged in pairs side by side. In both of these experiments the rows ran east and west, and were 18 feet long, cut to 16 feet in harvesting. The oats were drilled on March 12, at the rate of 10 pecks per acre. The yields of oats, particularly of the later-maturing varieties, were materially reduced by the hot dry weather in the middle of June. The yields of the oats varieties are shown in Table 7, and those of the strains in Table 8.

B	K	R	1	17	33	49	K	R	13	29	45	61	K	R	9	25	41	57	K	R	5	21	37	53	K	R	B
B	K	R	2	18	34	50	K	R	14	30	46	62	K	R	10	26	42	57	K	R	6	22	38	54	K	R	B
B	K	R	3	19	35	51	K	R	15	31	47	63	K	R	11	27	43	59	K	R	7	23	39	55	K	R	B
B	K	R	4	20	36	52	K	R	16	32	48	64	K	R	12	28	44	60	K	R	8	24	40	56	K	R	B
B	K	R	5	21	37	53	K	R	1	17	33	49	K	R	13	29	45	61	K	R	9	25	41	57	K	R	B
B	K	R	6	22	38	54	K	R	2	18	34	50	K	R	14	30	46	62	K	R	10	26	42	58	K	R	B
B	K	R	7	23	39	55	K	R	3	19	35	51	K	R	15	31	47	63	K	R	11	27	43	59	K	R	B
B	K	R	8	24	40	56	K	R	4	20	36	52	K	R	16	32	48	64	K	R	12	28	44	60	K	R	B
B	K	R	9	25	41	57	K	R	5	21	37	53	K	R	1	17	33	49	K	R	13	29	45	61	K	R	B
B	K	R	10	26	42	58	K	R	6	22	38	54	K	R	2	18	34	50	K	R	14	30	46	62	K	R	B
B	K	R	11	27	43	59	K	R	7	23	39	55	K	R	3	19	35	51	K	R	15	31	47	63	K	R	B
B	K	R	12	28	44	60	K	R	8	24	40	56	K	R	4	20	36	52	K	R	16	32	48	64	K	R	B
B	K	R	13	29	45	61	K	R	9	25	41	57	K	R	5	21	37	53	K	R	1	17	33	49	K	R	B
B	K	R	14	30	46	62	K	R	10	26	42	58	K	R	6	22	38	54	K	R	2	18	34	50	K	R	B
B	K	R	15	31	47	63	K	R	11	27	43	59	K	R	7	23	39	55	K	R	3	19	35	51	K	R	B
B	K	R	16	32	48	64	K	R	12	28	44	60	K	R	8	24	40	56	K	R	4	20	36	52	K	R	B
B	K	R	65	73	81	89	K	R	71	79	87	95	K	R	69	77	85	93	K	R	67	75	83	91	K	R	B
B	K	R	66	74	82	90	K	R	72	80	88	96	K	R	70	78	86	94	K	R	68	76	84	92	K	R	B
B	K	R	67	75	83	91	K	R	65	73	81	89	K	R	71	79	87	95	K	R	69	77	85	93	K	R	B
B	K	R	68	76	84	92	K	R	66	74	82	90	K	R	72	80	88	96	K	R	70	78	86	94	K	R	B
B	K	R	69	77	85	93	K	R	67	75	83	91	K	R	65	73	81	89	K	R	71	79	87	95	K	R	B
B	K	R	70	78	86	94	K	R	68	76	84	92	K	R	66	74	82	90	K	R	72	80	88	96	K	R	B
B	K	R	71	79	87	95	K	R	69	77	85	93	K	R	67	75	83	91	K	R	65	73	81	89	K	R	B
B	K	R	72	80	88	96	K	R	70	78	86	94	K	R	68	76	84	92	K	R	66	74	82	90	K	R	B

FIGURE 5.—PLANTING PLAN OF OATS VARIETY AND STRAIN TESTS 1921. Legend: B, border. K, Kherson check. R, Red Rustproof check. Numbers 1-64, planting numbers of oats strains, as given in Table 8. Numbers 65-96, planting numbers of oats varieties, as given in Table 7.

Table 7.—Yields of Oats Varieties.
In Bushels per Acre. 1921.

Planting number	Variety	Average yield 3 Interior Rows	5 Rows
65	Burt	49.13	51.94
66	Canadian	25.31	25.13
67	C. I. 603	22.50	23.06
68	Culberson	24.75	25.13
69	Danish Island	19.69	19.13
70	Early Dakota	21.56	21.56
71	Early Gothland	23.44	22.13
72	Garton 748	21.00	20.81
73	Green Russian	26.06	26.25
74	Irish Victor	29.81	32.06
75	Joanette	19.31	19.69
76	Fulghum 042	45.19	47.44
77	Monarch	29.63	31.88
78	Monarch Selection	35.63	36.38
79	Scottish Chief	26.63	27.38
80	Silvermine 050	31.69	32.06
81	Silvermine Selection	22.13	24.94
82	Sparrowbill (C)	15.38	14.63
83	Sterilis Selection	38.63	36.94
84	Storm King	20.06	17.63
85	Swedish Select 057	21.00	19.50
86	Fulghum 065	42.00	44.81
87	Fulghum 0113	42.00	45.38
88	Silvermine 0115	25.13	24.94
89	Silvermine 0117	21.75	22.69
90	Fulghum 0124	45.38	48.38
91	Fulghum 0145	39.19	41.81
92	Fulghum 0149	42.75	47.06
93	Fulghum 0151	39.75	43.88
94	Fulghum 0152	39.75	42.38
95	Silvermine 0165	28.31	26.81
96	Swedish Select 0165	20.81	18.56
	Mean	29.85	30.70

TABLE 8.—YIELDS OF OATS STRAINS (RED RUSTPROOF AND KHERSON). In Bushels per Acre. 1921.

Red Rustproof strains				Kherson strains			
		Average yields				Average yields	
Planting number	Strain	3 Interior Rows	5 Rows	Planting Number	Strain	3 Interior Rows	5 Rows
1	066	24.00	23.25	2	023	35.25	36.38
3	067	24.00	21.75	4	040	36.57	37.50
5	068	23.25	23.44	6	041	36.56	38.81
7	069	19.31	18.00	8	052	38.06	38.81
9	072	18.38	18.75	10	053	39.75	42.00
11	074	22.31	20.63	12	079	32.63	34.88
13	075	24.19	22.13	14	080	35.44	38.25
15	0118	16.50	16.31	16	082	40.88	41.44
18	0119	22.31	21.38	17	083	35.44	38.25
20	0120	21.19	19.69	19	085	38.25	41.81
22	0122	19.13	17.81	21	086	36.75	37.69
24	0125	21.00	19.88	23	Mixture**	33.75	36.38
26	0126	25.31	22.50	25	088***	27.00	27.56
28	0128	20.44	20.25	27	089	30.94	31.69
30	0129	21.94	21.56	29	090	36.38	38.06
32	0130	21.75	20.25	31	091	30.19	31.88
33	0131	24.56	23.25	34	094	31.69	33.56
35	0132	17.63	19.13	36	095	38.81	39.75
37	0133	18.94	18.75	38	096	36.38	38.06
39	0134	16.50	15.75	40	097	31.31	32.25
41	0135	17.63	15.65	42	098	38.63	39.19
43	0136*	32.44	33.19	44	099	38.81	38.25
45	0141	21.94	21.19	46	0100	40.13	42.75
47	0163	13.88	12.94	48	0155	37.50	38.63
50	0169	15.38	14.44	49	0157	43.69	45.00
52	0181	19.88	18.00	51	0158	34.69	35.25
54	0182	19.88	19.13	53	0159	33.38	33.94
56	0183*	41.44	43.31	55	0160	30.19	31.13
58	0383	23.63	24.00	57	0161	34.69	36.00
60	0391	29.44	30.19	59	0162	25.31	25.69
62	0394	22.31	21.56	61	0167	40.69	39.94
64	0395	23.25	21.94	63	0174	36.75	38.25
Mean		21.00	20.12	Mean		35.79	37.14

*Not taxonomically Red Rustproof. Excluded from average.

**Mixture of strains 082, 094, 0100, 0174.

***Not taxonomically Kherson. Excluded from average.

COMPETITION AS A SOURCE OF ERROR IN PRELIMINARY TESTS.

Previous Investigation.—The possibility of error from competition in single-row tests was noted by Montgomery[14] in 1913, in the following passage:

"In 1908 it was observed that a certain strain of early wheat in a series of row plats made a very poor appearance at harvest time, while the same strain planted in centgeners made a much better comparative showing. Apparently the larger and faster growing strains on each side, the rows being only 8 inches apart, exercised some competitive effect. This effect of competition has been noted for two years since. Also in certain variety tests of oats, grown in row plats 10 inches apart, the same effect was noted. Exact data cannot be given on this point, as the results from the series of plats planted in 1909 and in 1910 for this purpose were seriously impaired by unfavorable conditions; but Table XVIII, giving results from adjacent row plats sown at different rates, shows that the 800-seed rate made a marked increase over the 700-seed rate, while in a similar series of blocks (Table XIX), sown at the same rate, this marked increase was not noted. Since the 800-seed row was always adjacent to the 400-seed row, it may have had some advantage on this account. Danger from this source can probably be avoided if care is taken to plant only similar varieties in adjacent rows. Where the block plat is used this source of error is eliminated."

Hayes & Arny[4] found considerable competition between rod-rows grown one foot apart. Three-row plots were used in variety tests of winter wheat, spring wheat, barley, and oats, and the yields of each row determined separately, in 1916. The comparative yield of the border rows in each plot was then correlated with the comparative height and yield of the adjacent rows. There was some effect on the yield of border rows due to the height of adjacent rows in the case of barley and winter wheat. The results were variable in different plots. In the case of oats the effect of height was rather obscure, and in the case of spring wheat it was not apparent. The yield of adjacent rows appeared to be of some importance in the barley tests and in some of the spring wheat tests. These results led to the adoption of 3-row plots with discarded border rows for preliminary testing at the Minnesota Station.

Love and Craig[9] in describing the methods used in cereal investigations at the Cornell Station describe the single-row test and add: "In order to prevent any effect which may be caused by two unlike sorts growing together the different strains are arranged according to earliness and other characters so as to reduce this source of error to a minimum."

Kiesselbach[5,7] has published rather extensive data on the competition between adjacent rod-rows. In his experiments the crops were compared in alternating single-row plots and in alternating 5-row blocks, each replicated fifty times. In some cases the border rows of 5-row plots were discarded. The deviation of the result in the test in single-row plots from that of the test in 5-row plots is regarded as the measure of the effect of competition. The comparative yields of varieties of wheat and oats in alternating single rows and in alternating 5-row plots are shown in Table 9, from Kiesselbach[7].

TABLE 9.—RELATIVE YIELDS OF TWO SMALL GRAIN VARIETIES WHEN COMPARED IN ALTERNATING ROWS AND IN ALTERNATING 5-ROW PLATS (KIESSELBACH).

Wheat			Oats		
Average yield of 50 plats			Average yield of 50 plats		
Year and variety	Alternating single rows %	Alternating 5-row blocks* %	Year and Variety	Alternating single rows %	Alternating 5-row blocks* %
1913			1913		
Turkey	100	100	Kherson	100	100
Big Frame	107	97	Burt	130	112
1914			1914		
Turkey	100	100	Kherson	100	100
Big Frame	85	97	Burt	139	101
1913			1913		
Turkey	100	100	Kherson	100	100
Neb. No. 28	107	107	Swedish Select	82	77
1914			1914		
Turkey	100	100	Kherson	100	100
Neb. No. 28	63	85	Swedish Select	89	93

*Yield based on 3 inner rows of 5-row plats in 1914.

Kiesselbach also submits interesting data on the competition of pure line selections of the same variety. It might be supposed that such strains, being similar in varietal characteristics, would be little affected by competition, and could therefore be safely compared in single-row plots. The average relative yields of three strains of Turkey wheat in single rows and in blocks for two seasons, however, showed that the two better strains were favored approximately 20 per cent and 15 per cent, respectively, at the expense of the poorer strain, in the single-row test. A strain which yielded 26 per cent more than another in the single-row test yielded only 6 per cent more in the block

test. Kiesselbach has therefore adopted the practice of testing such strains in 5-row blocks replicated ten times instead of in single-row plots.

Love[8] has criticized these results because in some cases at least the rows ran east and west rather than north and south. He states that in experiments at Ithaca, New York, there is little competition between varieties grown in single rows, when the rows run north and south. "In order to obviate any criticism of this method," he adds, "it might be well to follow the plan of arranging varieties so that late sorts are grown together and the earlier ones together. In other words, the different sorts could be so arranged that they grade into one another as regards yield, earliness, and the like." To this Kiesselbach[6] replies that in some of his competition studies the rows ran north and south and in others east and west, and that striking competition occurred in both cases. He adds that although error resulting from row competition would undoubtedly be reduced by grouping varieties of similar growth habits together, it appears that varieties fairly similar in growth habit may vary for some reason in relative competitive quality.

Experimental Results.—Some further evidence on competition as a source of error in plot experiments is afforded by a study of the relative yields of border rows and interior rows in the 5-row blocks used in these preliminary tests. It should be remembered, of course, that the effect on yield would be decidedly greater in single rows exposed to competition on both sides than in these border rows, which compete with another sort on only one side. The extent of the error from competition in such border rows is of interest in determining whether it is necessary to discard the border rows of small blocks. When 5-row blocks are used, even if the border rows are not discarded, the relative effect of competition is greatly reduced, since only two of the five rows are subject to varietal competition and these are exposed only on one side. If this results in reducing the error from competition to a low point, or if varieties can be so arranged as to give this result, it may be advisable in practice to harvest 5-row blocks entire, thus avoiding the principal objection to the use of border rows—the loss of a considerable portion of the experimental area.

Competition is particularly important as a source of error because of the fact that it tends to affect replicate plots similarly, and consequently does not necessarily increase plot variability. For this reason it is likely to escape detection, and, when it is involved in an experiment, its effect cannot be measured. There is no great objection to a considerable experimental error from plot variability in field experi-

ments, if the experimenter determines the extent of the error and draws his conclusions accordingly. But a preliminary variety test in which error from competition is not controlled may be very nearly worthless as an indication of the relative value of varieties for field conditions, because actually the relative values of the varieties tested may frequently differ by 50 or 100 per cent from the values determined in the test, without the slightest indication in the experimental results.

Illustrations of Effects of Competition.—The error from competition may be illustrated by numerous examples from each of the eight tests here reported. An extreme case is the effect of competition on the relative yield of wheat and rye. Two varieties of rye, common rye and Rosen rye, were included in the wheat variety test, for comparison with wheat. The average yields of Rosen rye and of the varieties of wheat adjoining it on either side, in interior rows and competing border rows of the four series, were as follows:

Season	Variety	Yield in interior rows		Yield in competing border rows	
		Bushels	Relative	Bushels	Relative
1920	Niagara (Wheat)	13.8	67	10.0	33
	Rosen (Rye)	20.7	100	30.4 27.7	100 100
	Velvet Chaff No. 2 (Wheat	14.1	68	9.8	35
1921	Red Hussar (Wheat)	14.3	80	11.6	59
	Rosen (Rye)	17.9	100	19.7 25.4	100 100
	Poole (ck) (Wheat)	11.8	66	11.2	44

The disturbance of the true comparative value of the varieties by competition may be determined by comparing their relative yields in interior rows and in border rows. Thus Niagara wheat in 1920 yielded 67 per cent as much as Rosen rye in plots protected from competition, but only 33 per cent as much in rows not protected from competition. Similarly the yield of Velvet Chaff No. 2 wheat was reduced from 68 per cent to 35 per cent by competition with Rosen rye. In the following season the reduction in yield of the two varieties of wheat adjoining Rosen rye (Red Hussar and Poole) was not so great, but was still decidedly significant. This clear case of compe-

tition serves to illustrate the phenomenen, although the competition between wheat and rye has little significance in itself as regards variety tests in general, since wheat and rye are not commonly included in the same test.

Ordinarily the competition between varieties of the same crop is not so extreme. There are, however, a number of cases in which a variety of wheat or oats profited almost as extremely in competition with other varieties of the same crop as did the rye in competition with wheat in the cases cited above. The wheat variety, Michigan Wonder No. 116, which grew between two other wheat varieties, Leap's Prolific and Poole Selection, in 1921, gave the following results, as an average of the four series:

Variety	Yield in interior rows		Yield in competing border rows	
	Bushels	Relative	Bushels	Relative
Leap's Prolific	14.9	91	9.9	53
Michigan Wonder No. 116	16.4	100	18.8	100
			21.7	100
Poole Selection	15.3	93	11.5	53

The effect of competition in this case is almost as pronounced as in the case of the rye, although the three wheat varieties concerned, when protected from competition, gave almost equal yields and differed little in date of heading, date of maturity, and height. In this case a small difference in actual value between the varieties, as indicated by their yields when protected from competition, is greatly increased when their yields in adjacent single rows are compared.

A striking case of competition in the oats variety test of 1921 was that of the three varieties Sterilis Selection, Fulghum, and Kherson, the check variety. Their average yields were as follows:

Variety	Yield in interior rows		Yield in competing border rows	
	Bushels	Relative	Bushels	Relative
Sterilis Selection	38.63	99	28.50	58
Fulghum	39.19	100	48.75	100
			42.94	100
Kherson (check)	40.69	104	34.18	70

These three varieties, which gave almost equal yields in rows protected from competition, differed decidedly in their yields in adjacent rows. Although Kherson outyielded Fulghum 4 per cent in plots protected from competition, its yield was 30 per cent less than that of Fulghum in single rows not protected from competition.

Extreme effects of competition were shown in very numerous cases in the tests of Kherson and Red Rustproof strains in 1921. An example from this plot is the following:

Strain	Yield in interior rows		Yield in competing border rows	
	Bushels	Relative	Bushels	Relative
0169 (Red Rustproof check)	18.38	77	22.31	119
			18.75	100
067 (Red Rustproof)	24.00	100		——
			17.44	100
085 (Kherson)	38.25	159	51.94	298

The extreme advantage of the Kherson strain in competition with the Red Rustproof, increasing its margin of superiority from 59 per cent to 198 per cent, is particularly striking. Probably even more significant is the effect of competition between the two Red Rustproof strains, resulting in the conversion of a 23 per cent loss to a 19 per cent gain.

All of the cases cited above are taken from plots in which the rows ran east and west. Some examples of varietal competition from tests in rows running north and south are the following:

In the barley variety test, the variety Featherston 1118 occurred between Red River 973 and Oderbrucker (the check variety). The average yields of these three varieties in the three series were as follows:

Variety	Yield in interior rows		Yield in competing border rows	
	Bushels	Relative	Bushels	Relative
Red River 973	27.25	96	31.20	127
			24.60	100
Featherston 1118	28.25	100		——
			25.65	100
Oderbrucker (ck)	34.87	123	42.19	164

In this case the advantage of Oderbrucker over Featherston was almost tripled by competition, and Red River, which yielded less than Featherston in the interior rows, excelled it materially in yield in the border rows.

The oats varieties tested in rows running north and south in 1919 showed marked effects of competition in several cases. The following will serve as an example:

Variety	Yield in interior rows		Yield in competing border rows	
	Bushels	Relative	Bushels	Relative
Kherson Selection	61.3	111	84.7	171
			49.4	100
Fulghum 042	57.1	100		——
			50.7	100
Lincoln	50.3	88	57.5	113

In this case Lincoln, yielding 12 per cent less than Fulghum in interior rows, yielded 13 per cent more than Fulghum in border rows; while the advantage of Kherson Selection over Fulghum was increased from 11 per cent to 71 per cent.

Marked competition is hardly to be expected in the oats strain test of 1919, regardless of the direction of the rows, because of the similarity of the strains in varietal characters. Three strains which proved to be taxonomically unlike Red Rustproof were included in this test, and each of these shows clearly the effects of competition. For example, strain 0124, which was classified as Fulghum, gave the following yields in comparison with the adjoining strains, 0127, classified as Kherson, and 0133, classified as Red Rustproof:

Strain	Yield in interior rows		Yield in competing border rows	
	Bushels	Relative	Bushels	Relative
0127 (Kherson)	38.55	60	32.40	48
			66.83	100
0124 (Fulghum)	63.90	100		——
			78.75	100
0133 (Red Rustproof)	48.00	75	43.20	55

Moreover, the Red Rustproof strains showed competitive effects among themselves to some extent, though not so conspicuously as different varieties. For example the strains 0122 and 0123, which were taxonomically identical, yielded as follows:

Strain	Yield in interior rows		Yield in competing border rows	
	Bushels	Relative	Bushels	Relative
0122 (Red Rustproof)	47.85	89	55.13	112
0123 (Red Rustproof)	53.55	100	49.28	100

Strain 0122 which was apparently 11 per cent inferior to strain 0123 in the yields of interior rows, appeared to be 12 per cent superior to the same strain in the yields of their adjacent border rows.

In the wheat mixture test of 1920 also the rows ran north and south. An example of competition from this test is the following:

Variety	Yield in interior rows		Yield in competing border rows	
	Bushels	Relative	Bushels	Relative
Poole (check)	15.1	81	14.5	60
Michigan Wonder No. 221	18.6	100	24.2 21.4	100 100
Kanred	13.6	73	12.5	58

In this case also differences in yield were increased by competition.

The individual cases cited above will serve to show the existence of competition as a source of error in these tests. As a result of competition the differences between varieties may be increased or decreased, and in some cases a material advantage in yield may be converted to a material disadvantage. The phenomenon occurs, under conditions at Columbia, whether the rows run north and south or east and west. Of course it is not true that all of the difference in yield between border rows and interior rows is necessarily caused by varietal competition. Some variation in the yield of adjacent rod-rows will occur regardless of competition. When the means of only

four determinations are compared the effect of this variability may be considerable. If a field uniformly seeded to a single strain were harvested in rod-rows and assumed to be made up of several different varieties each in four distributed plots, doubtless the average border yield would differ materially from the average interior yield in several "varieties." It is not however, likely, that such differences as those cited above would be caused by chance variability. Nevertheless, no final conclusions regarding competition as a source of error should be drawn from such individual cases. The extent of error from competition is better shown in the average differences between border yields and interior yields, and in the mean coefficients of competition for complete tests. They are given in the next section.

Relation of Competition to Various Characteristics of the Competing Varieties.—It is essential that competition be eliminated by the use of border rows, or counteracted by some such means as grouping varieties. The latter is decidedly the preferable method, from the standpoint of economy, if satisfactory results may be obtained by its use. But competition cannot be effectively controlled by grouping varieties unless there is a close correlation between competitive value and some character like earliness or height, which may be known in advance. Determinations of the correlation between competitive effects and various characteristics of the varieties have therefore been made for each of the tests. The preliminary determinations were made as follows:

(1) The average yield in interior rows and the average yield in the border rows on each side for all replicate plots of each variety or strain was determined. The replicate plots thus averaged were grown between the same varieties in each series, and it may be assumed therefore that their border rows were subject to the same competition. In the following discussion of competition each individual case represents the mean of all the replicate plots of the test in question. For example, when it is stated that the correlation between competition and yield is determined in a test in which one hundred cases of competition are involved, each of the hundred cases represents the mean of three or four determinations in replicate plots. In most cases the number of replicate plots was four. In the barley test of 1919 only three series were grown, and in the oats variety test of 1919, though four series were grown, only three could be used because one border row of each variety in the first series was harvested for seed and laboratory material.

(2) Corresponding average yields were determined for check plots, those adjoining the same variety being averaged together. For

example, in the wheat variety test diagrammed in figure 1 the four check plots which adjoined variety 1 (one in each series) were averaged together, the four adjoining variety 2, the four adjoining variety 3, etc. The four check plots adjoining varieties 89, 90, 91, etc. were similarly averaged.

(3) The average yield of each border row for each variety was converted to the percentage of the average yield of the same variety in its interior rows. These yields of border rows in percentage will be referred to as "relative border yields." The relative border yield gives a rough indication of the effect of competition on the variety. When it is above 100, the variety yielded more in border rows (subject to competition) that in interior rows (protected from competition). When it is below 100, the border yield was less than the interior yield, in proportion.

(4) An approximate measure of the competition between each pair of adjacent varieties was obtained by dividing the higher relative border yield by the lower, in the case of their adjacent border rows, and substracting 100 from the result. When the variety on the left has a higher relative border yield, this is given a positive sign; in the reverse case a negative sign. This figure is simply the predominance of the more strongly competing variety over the other in percentage of relative border yield. It will be referred to, for convenience, as the coefficient of competition.

(5) This measure of competition was correlated with various characteristics of the competing varieties, including the relative yields in interior rows, the relative grain-straw ratios, the relative dates of heading and of maturity, and the relative heights. In correlating competition with the relative yield of the interior rows, the relative yield was determined by dividing the higher yield by the lower, subtracting 100, and assigning a positive or negative sign, as before. The correlation determined, therefore, is the correlation between the percentage advantage of one variety over another in competition, and the difference in yield of the two varieties, expressed in percentage, when protected from competition. Relative grain-straw ratios were determined similarly, the ratios being first obtained by dividing the yield of straw by the yield of grain. Relative dates of heading and maturity and relative heights were determined simply by subtracting the value for one variety from the value for the other. In each case, of course, the sign was determined in the same way.

A simple example explained in detail may serve to make this method clear. In the wheat variety test of 1921 the varieties Fultz (Bayer), Michigan Amber, and Michigan Wonder No. 211 occurred

in the order named in four distributed sections of the field. The average yields of these varieties in the four series, in bushels per acre, for border rows and for interior rows, are shown below, together with the average dates of heading, dates of maturity, and heights, also determined for the four series.

	23. Fultz (Bayer)			39. Michigan Amber			55. Michigan Wonder No. 211		
	Row 1	Row 2, 3, 4	Row 5	Row 1	Row 2, 3, 4	Row 5	Row 1	Row 2, 3, 4	Row 5
Average yields	10.8 bu.	12.2 bu.	13.1 bu.	13.3 bu.	14.9 bu.	14.5 bu.	19.8 bu.	18.1 bu.	19.4 bu.
Average date of heading		21*			21*			19*	
Average date of maturity		47*			48*			47*	
Average height		43 in.			42 in.			43 in.	

* Dates of heading and maturity are the numbers of days after April 30. Thus 1 is May 1, 32 is June 1, 47 is June 16, etc.

Now dividing the yields in border rows by the yields of the same varieties in interior rows, we obtain the relative border yields, which are substituted in the table below for the border yields in bushels. To determine the degree of competition between the varieties Fultz and Michigan Amber we divide the larger relative border yield (107) by the smaller (89) and subtract 100, giving 20 per cent. Since in this case the relative border yield of the variety on the left is higher, the difference is given a minus sign. Similarly a value of +12 per cent is obtained for the competition between Michigan Amber and Michigan Wonder No. 211. These figures mean that the relative border yield of Fultz exceeded that of Michigan Amber by 20 per cent in their competing border rows, while that of Michigan Wonder exceeded that of Michigan Amber by 12 per cent.

The relative yields of these varieties are obtained similarly,—in the first case by dividing 14.9 by 12.2 (+22%) and in the second case by dividing 18.1 by 14.9 (+21%). Both values are positive because in each case the yield of the variety on the left is higher than that of the variety on the right. The difference in dates of heading, maturity, and height are obtained simply by subtraction, being positive when the value of the variety on the right is greater and negative when

the value of the variety on the left is greater. The figures ready for correlation study will then appear as follows:

	23. Fultz (Bayer) Row 1	Row 2, 3, 4	Row 5	Competition data	39. Michigan Amber Row 1	Row 2, 3, 4	Row 5	Competition data	55. Michigan Wonder No. 211 Row 1	Row 2, 3, 4	Row 5
Average yield	89	12.2	107	−20% +22%	89	14.9	97	+12% +21%	109	18.1	107
Average date of heading		21		0		21		−2		19	
Average date of maturity		47		+1		48		0		47	
Average height		43		−1		42		+1		43	

The columns headed "competition data" show the relation of the effect of competition to the yield, earliness, and height of the competing varieties. For example, Michigan Amber was at a disadvantage of 20 per cent in competition with Fultz, though it was 22 per cent superior in yield when protected from competition. It headed the same day, matured one day later, and was one inch shorter. After corresponding data had been prepared for all the 96 varieties in this test, correlation tables with the coefficient of competition as subject and relative yield, date of heading, date of maturity, and height as relative were constructed. Correlations were determined similarly in the other tests. One of these correlation tables is shown in figure 6. In general, merely

	−100 to −120	−80 to −100	−60 to −80	−40 to −60	−20 to −40	0 to −20	0 to 20	20 to 40	40 to 60	60 to 80	80 to 100	Total
−40 to −60						1						1
−20 to −40	2	1	1	2	4	2	2					14
0 to −20			1	1	7	10	5	2				26
0 to 20			1	2	6	10	8	3	5			35
20 to 40					2	3	4	11	2	1	1	24
40 to 60					1		1			3		5
60 to 80							1		1	1		3
Total	2	1	3	5	20	26	21	16	8	5	1	112

FIGURE 6.—CORRELATION BETWEEN COEFFICIENT OF COMPETITION AND RELATIVE YIELD, IN WHEAT VARIETY TEST 1920.
$r = +.582 \pm .043.$

the coefficient of correlation and its probable error are given, for lack of space.

In the barley variety test, 1919, the effect of competition was quite marked. The average yield of border rows differed from the average yield of interior rows by 11.13 per cent, and the mean coefficient of competition was 21.30 per cent. Attempts were made to correlate competition with relative date of heading, date of maturity, grain-straw ratio, and yield. The correlation coefficients determined are shown in Table 10, together with the mean differences between competing varieties in the characters whose relation to competition was studied.

TABLE 10.—CORRELATION OF COMPETITION WITH VARIOUS CHARACTERISTICS IN BARLEY VARETY TEST 1919.

Character	Mean difference between competing varieties	Coefficient of correlation with competition
Date of heading	4.0 days	—.153 ±.120
Date of maturity	2.6 days	—.063 ±.123
Grain-straw ratio	38.0%	+.072 ±.122
Yield	52.3%	+.442 ±.099

Although none of these correlations is statistically significant, in the strictest sense, it is noticeable that the correlation between competition and yield is much greater than any of the others, and is equal to about four and one-half times its probable error. There was apparently some tendency for the better yielding varieties to profit by competition with the poorer yielders. On account of the relatively small number of cases involved in this and the other 1919 tests, the probable errors are high, and a fairly high coefficient of correlation may consequently fail to attain statistical significance. Such a coefficient, while not establishing the correlation, by no means indicates that the correlation does not exist.

TABLE 11.—CORRELATION OF COMPETITION WITH VARIOUS CHARACTERISTICS IN OATS VARIETY TEST 1919.

Character	Mean difference between competing varieties	Coefficient of correlation with competition
Date of maturity	3.56 days	—.456 ±.103
Grain-straw ratio	50.2%	—.091 ±.129
Yield	53.5%	+.314 ±.117

The oats variety test of 1919 also showed distinctly the effects of competition. The border rows in this test differed in yield from the interior rows by 12.78 per cent, on the average, and the mean coefficient of competition was 27.67 per cent. Correlations were determined for competition and relative yield, date of maturity, and grain-straw ratio. Unfortunately the dates of heading are not available for all varieties in this test. The correlation coefficients are shown in Table 11.

Again no correlations of statistical significance are found, but the relation of yield and earliness of maturity to competing strength is at least suggestive. There was a tendency for early and high-yielding varieties to profit by competition at the expense of later and lower-yielding varieties, but the number of varieties was too small to permit the drawing of positive conclusions.

The oats strains grown on the same field showed much less strikingly the effects of competition. The mean difference in yield between border rows and interior rows in these 15 strains was only 6.50 per cent and the mean coefficient of competition only 13.11 per cent. This is undoubtedly accounted for by the fact that the differences between competing strains were so much less than in the oats variety test. When the three strains taxonomically unlike Red Rustproof are eliminated, leaving 12 strains of the same variety, the average deviation of border yields from interior yields is reduced to 4.69 per cent and the average coefficient of competition to 8.69 per cent. It is noteworthy that the competition between these strains of the same variety is decidedly less than that between different varieties. No significant correlation was found between these minor effects of competition (for the 15 strains) and the relative time of heading, time of maturity, grain-straw ratio or yield, as is shown in Table 12, though in this case again the early strains and the high-yielding strains showed some tendency to profit by competition.

TABLE 12.—CORRELATION OF COMPETITION WITH VARIOUS CHARACTERISTICS IN OATS STRAIN TEST 1919.

Character	Mean difference between competing strains	Coefficient of correlation with competition
Date of heading	2.67 days	—.376 ±.136
Date of maturity	1.56 days	—.244 ±.149
Grain-straw ratio	14.2%	+.012 ±.159
Yield	17.1%	+.316 ±.143

In the wheat variety test of 1920 the average yield of border rows differed from the average yield of interior rows by 12.30 per cent and the mean coefficient of competition was 19.79 per cent. These figures represent the average determinations when the two varieties of rye and the border yields of the varieties of wheat adjoining them were eliminated. The correlation between competition and relative yield, date of heading, and date of maturity were determined for this test and the coefficients of correlation are shown in Table 13.

TABLE 13.—CORRELATION OF COMPETITION WITH VARIOUS CHARACTERISTICS IN WHEAT VARIETY TEST 1920.

Character	Mean difference between competing varieties	Coefficient of correlation with competition
Date of heading	2.3 days	—.515 ±.048
Date of maturity	2.7 days	—.552 ±.045
Yield	28.9%	+.582 ±.043

Competition in this test was negatively correlated with earliness of heading and maturity and positively with yield. All of the correlation coefficients are clearly significant. In other words, there was a rather pronounced tendency for the early and high-yielding varieties to profit in competition. To a considerable extent the early varieties were the high yielding varieties in this test, as indicated by the fact that the correlation coefficient for date of heading and yield was —.511 ±.051, and that for date of maturity and yield was —.642 ±.041. Although it is clear from these results that early, high-yielding varieties excelled in competition, it is not clear whether they did so chiefly as a result of their earliness or chiefly as a result of their yield.

TABLE 14.—CORRELATION OF COMPETITION WITH VARIOUS CHARACTERISTICS IN WHEAT VARIETY TEST 1921.

Character	Mean difference between competing varieties	Coefficient of correlation with competition
Date of heading	2.1 days	—.271 ±.060
Date of maturity	1.6 days	—.222 ±.062
Height	3.3 inches	+.347 ±.057
Yield	19.5%	+.294 ±.059

Similar results were obtained in the wheat variety test of 1921 in which the difference between the average yield of border and interior rows was 12.89 per cent and the mean coefficient of competition

was 18.85 per cent. Correlations were determined for competition and relative yield, date of maturity, date of heading, and height in this test. The coefficients of correlation thus determined are shown in Table 14.

In this case, as in the wheat variety test of the preceding season, dates of heading and maturity were correlated negatively and yield was correlated positively with competition. The coefficients of correlation were materially lower, and in fact are hardly significant. It is interesting that in this case height was correlated more closely with competition than were either earliness or yield. In this season again earliness was correlated to some extent with yield, the coefficients of correlation, for date of heading and yield being —.331 ±.062 and for date of maturity and yield —.419 ±.057.

In the wheat mixture test of 1921 the varieties were grouped roughly in respect to earliness, and in only three cases was there a greater difference than two days in heading or maturity between adjacent varieties. The rows in this test ran north and south. The conditions may be considered favorable in this test for the reduction of competition. Nevertheless the average yield of border rows differed from that of interior rows by 10.07 per cent and the mean coefficient of competition was 14.28 per cent. The coefficients of correlation determined for competition and date of heading, date of maturity, and yield, are shown in Table 15.

TABLE 15.—CORRELATION OF COMPETITION WITH VARIOUS CHARACTERISTICS IN WHEAT MIXTURE TEST 1921.

Character	Mean difference between competing varieties	Coefficient of correlation with competition
Date of heading	1.2 days	—.514 ±.083
Date of maturity	0.8 days	—.613 ±.070
Yield	19.2%	+.554 ±.078

In this test significant negative correlations between competition and dates of heading and maturity and a significant positive correlation between competition and yield are shown. The tendency for early, high-yielding varieties to profit by competition was about as strong as in the wheat variety test of the preceding season, though the extent of competitive effect was considerably reduced.

The effects of competition in the oats variety test in 1921 were extreme. The yields of border rows differed by 16.74 per cent, on the average, from the yields of interior rows, and the mean coefficient of competition was 39.15 per cent. The extreme effects of compe-

tition in this test are probably accounted for by the fact that the varieties differed very widely in varietal type and in yield. Differences of as much as 17 days in date of heading, 13 days in date of maturity, and almost 200 per cent in yield, were involved. The correlations determined between competition and relative date of heading, date of maturity and yield, are shown in Table 16.

TABLE 16.—CORRELATION OF COMPETITION WITH VARIOUS CHARACTERISTICS IN OATS VARIETY TEST 1921.

Character	Mean difference between competing varieties	Coefficient of correlation with competition
Date of heading	4.8 days	—.648 ±.060
Date of maturity	4.1 days	—.860 ±.028
Yield	51.1%	+.484 ±.082

A remarkably high negative correlation between date of maturity and competition is shown. The negative correlation between date of heading and yield is also quite high, while the positive correlation between yield and competition is barely significant. In this test, in which extreme differences in time of maturity occurred, the early-maturing varieties had a very distinct advantage in competition with the later varieties. Earliness was very closely correlated with yield in the oats variety test of this season, the coefficient of correlation for date of heading and yield being —.750 ±.052 and that for date of maturity and yield being —.894 ±.024. Considering the close correlation of earliness and yield, and the relatively low correlation of yield and competition, it would seem that the latter may be merely a by-product of the relation of earliness to competition. Since the early varieties were the leaders both in competition and in yield, some correlation of yield and competition is inevitable.

In the oats strains test of 1921 Kherson and Red Rustproof strains were alternated and both a Kherson and a Red Rustproof check were grown. In most cases therefore the competing border rows represented these two varieties, though in some cases two Red Rustproof or two Kherson plots occurred together, as is shown in the planting plan in figure 5. The effects of competition in this plot were quite distinct, as is to be expected, though they were not so extreme as in the oats variety test discussed above, which was located on the same field. The average yield of border rows differed from the average yield of interior rows by 11.76 per cent. The mean coefficient of competition was 23.85 per cent.

When we exclude the competition between the three strains not true to name and the strains adjacent to each, that between the Kher-

son and Red Rustproof check plots, and that between adjacent strains of the same variety, 58 cases of competition between different strains of Kherson and Red Rustproof remain. In these the mean yield of border rows differed from that of interior rows by 14.06 per cent and the mean coefficient of competition was 30.86 per cent. In every case the Kherson strain outyielded the adjacent Red Rustproof strain, though the advantage in yield varied from 27 per cent to 165 per cent. Similarly, the Kherson strains were earlier in maturity and heading, and taller, in each case, but with a rather wide variation in the extent of their advantage. In all but three of the 58 cases the Kherson strains showed a greater advantage in yield over the adjacent Red Rustproof strains in their competing border rows than in their interior rows. The average yields of the 30 Red Rustproof strains and 29 Kherson strains, in interior rows and competing border rows, were as follows:

	Average yield in interior rows		Average yield in competing border rows	
	Bushels	Relative	Bushels	Relative
Red Rustproof strains	21.00	100	18.59	100
Kherson strains	35.79	170	41.00	222

The Kherson strains outyielded the Red Rustproof strains by 70 per cent in their interior rows and by 122 per cent in their competing border rows. The coefficients of competition, like the relative yield, earliness, and height, varied rather widely. Correlations were therefore measured for the advantage of the Kherson strain of each adjacent pair in competition and its advantages in yield, date of heading, date of maturity, and height. The coefficient of correlation in each case was insignificant.

Discussion.—In each of these tests, with the exception of the oats strain test of 1919, in which most of the strains compared belonged to the same variety, border rows differed from interior rows in yield by more than 10 per cent. Differences as great as this will change materially the relative standing of varieties. In single-row tests the effects of competition would be considerably greater than in these border rows, affected by competition on only one side. Furthermore, in each test, of course, there were many cases in which competition caused much larger differences in yield than are shown by average figures.

The relation of the direction of rows to the effects of varietal competition is not clearly shown by these experiments. The tests which showed least the effect of competition, the oats strain test of 1919 and the wheat mixture test of 1921, were in rows running north and south. But relatively little effect from competition is to be expected in these tests, regardless of the direction of the rows, because of the similarity of adjacent strains. In the oats strain test 12 of the 15 strains were taxonomically identical, and it has been shown that the effects of competition among these was much less than among the strains of different varieties. In the wheat mixture test the varieties making up each mixture, which were grown side by side in the test, were chosen partly for their similarity in time of maturity, and the differences between adjacent varieties were therefore considerably less than in the wheat variety test of the same season. It cannot be stated definitely, therefore, from the results of these tests, that tests in rows running north and south are either more or less subject to error from competition than tests in rows running east and west. It is clear, however, that a considerable error from varietal competition may occur in tests in which the rows run north and south, as is evidenced particularly by the barley and oats variety tests of 1919.

The relation of competition to relative date of heading, date of maturity, grain-straw ratio, height, and yield, insofar as it was investigated in these experiments, is shown in summary form in Table 17. Although none of these characteristics shows a significant relation to competition in every case, the results of the tests are fairly consistent. The correlation of competition with yield is always positive, and is fairly high in every case, the lowest coefficient being +.294 ±.059. From these results there can be no doubt that the higher yielding varieties are those which in general have profited by competition. The date of heading and the date of maturity show a negative correla-

TABLE 17.—SUMMARY OF EFFECTS OF COMPETITION IN ALL TESTS.

Test	Season....	Number of varieties or strains....	Mean coefficient of competition...	Coefficient of Correlation between Competition and—				
				Date of Heading.	Date of Maturity.	Grain-Straw Ratio.	Height.	Yield.
Barley variety	1919	27	21.30	−.153±.120	−.063±.123	+.072±.122	....	+.442±.099
Oats variety	1919	24	27.67	....	−.456±.103	−.091±.129	....	+.314±.117
Oats strain	1919	15	13.11	−.376±.136	−.244±.157	+.012±.159	....	+.316±.143
Wheat variety	1920	94	19.79	−.515±.048	−.552±.045	....	....	+.582±.043
Wheat variety	1921	94	18.85	−.271±.060	−.222±.062	....	+.347±.057	+.294±.059
Wheat mixture	1921	30	14.28	−.514±.083	−.613±.070	....	....	+.554±.078
Oats variety	1921	32	39.15	−.648±.060	−.860±.028	....	....	+.484±.082

tion with competition in each case, though some of the coefficients are insignificant. It is clear therefore that early varieties are, in general, able to compete more strongly, but the extent of this relation is quite variable. The grain-straw ratio showed no significant relation to competition in any of the experiments of 1919, and was not determined for the succeeding tests. Height was correlated positively with competition in the one test in which height was determined, the wheat variety test of 1921. In this test height was more closely related to competition than were date of heading, date of maturity, or yield.

In the oats variety tests, the relation of early maturity to competion is particularly marked, the coefficients of correlation in both oats variety tests being distinctly greater for date of maturity and competition than for yield and competition. In the wheat tests there was little difference in the degree of relation to competition between earliness and yield. In the one test of barley varieties conducted, yield was more closely correlated with competition than was either the date of heading or date of maturity, but none of the three showed a clearly significant correlation.

It is clear that in these trials the early, high-yielding varieties profited by competition. To a considerable extent these may be the same varieties, for the correlation of earliness and yield was high in most of the tests conducted. The relation of earliness and other characters to yield under Missouri conditions will be considered more fully in another paper, but data of interest in this connection are appropriate here. The coefficients of correlation of yield with date of heading and date of maturity in the variety tests discussed in this paper are shown in Table 18.

TABLE 18.—CORRELATION OF YIELD WITH DATES OF HEADING AND MATURITY IN VARIETY TESTS OF BARLEY, OATS, AND WHEAT

Crop	Season	Number of varieties	Coefficient of correlation of yield with— Date of heading	Date of maturity
Barley	1919	27	—.281 ±.120	—.271 ±.120
Oats	1919	40	------------	—.627 ±.065
Oats	1921	32	—.750 ±.052	—.894 ±.024
Wheat	1920	94	—.511 ±.051	—.642 ±.041
Wheat	1921	94	—.331 ±.062	—.419 ±.057

When a very high correlation exists between earliness and yield it is likely that a character closely correlated with one may show a high degree of correlation with the other, which might not be shown were it not for the first correlation. For example, suppose earliness

of maturity is largely responsible for strong competitive value. Then in a season when earliness is closely correlated with yield a close correlation of competition and yield is likely to be found, not because high yield makes for strong competition but because the high-yielding varieties are early. Conversely, the competing value may be dependent on the yield and the correlation with earliness may be incidental, under the same conditions. If the relation of earliness and yield were constant, such a question would have little practical importance, but when the relation is reversed, as it may be in different localities and even in different seasons in the same locality, the relation of competition to the two characteristics may be very different. The relation of competition to earliness and yield in these tests, therefore, may be due primarily to the predominating influence of either of these two characteristics, or to the influence of both.

General conclusions regarding competition should not be drawn from these tests. The problem of competition is complicated by many factors, and will require numerous and extensive investigations for its solution. These results, however, indicate that gross errors from this source are commonly involved in variety tests, that such errors occur both in rows running east and west and in rows running north and south, that the error is less when the varieties and strains compared are structurally similar than when they are widely different, and that the error may be reducible to some extent by the grouping of varieties according to the time of maturity and possibly other characters, when the relation of such characters to competition is more fully studied. In the present state of knowledge regarding the relation of competition to the characteristics of the varieties compared, the use of border rows is highly desirable, since by their use the error from competition can be practically eliminated.

SIZE AND REPLICATION OF PLOTS.

Previous Investigation.—Most of the direct evidence reported on replication and size of plots has been obtained in experiments in which a field of a uniformly handled crop is harvested in a large number of small sections. These sections are grouped to form plots of different shapes and sizes, and systematically distributed sections are averaged to represent replicate plots. The relative variability of the yields determined by each plot arrangement is the criterion of experimental accuracy. Such experiments have been reported by Morgan[15] with wheat and fodder corn, Wood and Stratton[18] with mangels, Mercer and Hall [12] with wheat and mangels, Hall and Russell[3] with wheat,

Montgomery[13,14] with wheat, Kiesselbach[5] with oats, and Day[1] with wheat.

The general conclusions drawn from these experiments are in harmony, though the specific size and shape of plot and number of replications found most desirable vary rather widely. In general, plot variability was reduced by increasing the size of the individual plot, up to a certain limit, but it was reduced much more effectively by replication of plots. For a given area a large number of small plots was always found more accurate than a small number of large plots.

But the size of the plot cannot be reduced indefinitely for several reasons. As the plot becomes smaller the proportion subject to "border effect" rapidly becomes greater. This border effect may be due to the modified growth of plants adjoining an alley or to the influence of the competition of different varieties in adjacent rows. If the borders are not discarded an important systematic error is involved; if they are discarded a considerable portion of the land and labor is lost. In either case the disadvantage is increased as the size of the plot is decreased. When single rod-row plots are used the whole plot is subject to border effect. The importance of this error has already been discussed. Another disadvantage of the extremely small plot is that slight differences in stand and small mechanical errors have a marked effect on the yields. The increased labor involved in handling a large number of small plots rather than a small number of large plots is also an important disadvantage.

The length of the so-called rod-row has usually been determined by convenience. Commonly used lengths when the rows are a foot apart are 16 feet for wheat, 20 feet for barley, and 15 feet for oats, since with these lengths yields in grams per row may easily be converted to bushels per acre. In other cases the most convenient length is determined by the dimensions of experiment fields. Although increasing the length of the row would doubtless reduce variability, a greater gain could be made on the same area by further replication. Ordinarily it is preferable, therefore, to retain the most convenient length and to make any desired increase in size of plot in the width, for widening the plots will rapidly reduce the proportion subject to border effect.

Experimental Results. —*Size of Plots.*—By comparing the standard deviations of single rows and blocks consisting of three and five rows each, in the check plots, it is possible to determine the relative value of plots of the three sizes in counteracting plot variability. In this comparison the single-row and three-row plots correspond respectively to 3-row and 5-row plots in which the border rows are dis-

carded, since they are made up of rows protected from varietal competition by border rows. In each of the computations summarized below each check plot is represented by only one yield. For example, in determining the yield and standard deviation of single rows in the 20 check plots of the oats variety test of 1919, the constants for single rows are the average of determinations made independently for Row 2 of each of the 20 plots, for Row 3, and for Row 4. The determinations for 3-row plots are similarly made from the computed yields of the three interior rows of each check plot, and those for 5-row plots from the computed yields of the entire plots. Thus each determination represents the same number of plots and the same area, the only difference being in the size of the individual plot. It would be possible, of course, to test 40 per cent more varieties with the same number of replications or to increase the number of replications by 40 per cent for the same number of varieties on the same area, if 3-row blocks were used rather than 5-row blocks.

The yield and variability of check plots of different sizes in the barley variety test of 1919 are shown in Table 19. The variety grown in these check plots was Oderbrucker, seeded at the rate of 8 pecks per acre. The check variety was grown in every sixth plot.

TABLE 19.—YIELD AND VARIABILITY OF CHECK PLOTS.
Single-row, Three-row, and Five-row—Barley Variety Test 1919.

Size of plot	Number of plots	Yield per acre	Standard deviation	
		bu.	bu.	%
Single-row				
Row 1	21	41.26	7.95	19.26
Row 2	21	36.71	8.30	22.61
Row 3	21	37.15	8.48	22.84
Row 4	21	35.82	10.37	28.96
Row 5	21	42.12	11.86	28.16
Mean of three interior rows	21	36.56	9.05	24.80
Mean of five rows	21	38.61	9.39	24.37
Three-row Plot (Interior rows)	21	36.56	8.11	22.18
Five-row Plot	21	38.61	8.29	21.47

The variability of the single-row plots is 12 per cent higher on the average than that of the 3-row plots. That is, 3-row plots with

borders discarded would have given in this case somewhat more variable results than 5-row blocks with borders discarded. The same 5-row blocks harvested entire (with borders retained) gave slightly less variable yields than when the borders were discarded.

The same comparison may be made in the check plots of the oats variety test of 1919. The check variety was Red Rustproof, drilled at the rate of 10 pecks per acre in every ninth plot. The results are shown in Table 20.

Table 20.—Yield and Variability of Check Plots.
Single-row, Three-row, and Five-row—Oats Variety Test 1919.

Size of plot	Number of plots	Yield per acre	Standard deviation	
		bu.	bu.	%
Single-row				
Row 1	20	44.64	10.37	23.23
Row 2	20	47.97	9.81	20.45
Row 3	20	46.56	11.42	24.53
Row 4	20	46.95	13.81	29.41
Row 5	20	42.09	11.58	27.51
Mean of three interior rows	20	47.16	11.68	24.80
Mean of five rows	20	45.64	11.40	25.03
Three-row Plot (Interior rows)	20	47.16	10.62	22.59
Five-row Plot	20	45.64	9.72	21.30

The results in this case are practically identical with those of the barley variety test. Protected single rows were 10 per cent more variable than protected 3-row blocks, while the latter were only 6 per cent more variable than unprotected 5-row blocks.

In the test of strains of Red Rustproof oats, conducted on the same field in 1919, adjoining the oats variety test, the same variety was used as check, and the crop was seeded on the same day with the same machine, but the check plots were in every sixth instead of every ninth plot. The corresponding data for these check plots are given in Table 21.

Although the variability of these plots is lower, the relative variability of plots of different sizes is similar to that of the variety test. The single interior rows are on the average 24 per cent more variable than the 3-row block. The 3-row plot is only very slightly more variable than the 5-row plot.

TABLE 21.—YIELD AND VARIABILITY OF CHECK PLOTS.
Single-row, Three-row, and Five-row.—Oats Strain Test 1919.

Size of plot	Number of plots	Yield per acre	Standard deviation	
		bu.	bu.	%
Single-row				
Row 1	18	41.87	6.35	15.15
Row 2	18	40.88	5.52	13.51
Row 3	18	43.50	5.81	13.37
Row 4	18	45.00	7.31	16.25
Row 5	18	41.50	6.37	15.35
Mean of three interior rows	18	43.13	6.21	14.38
Mean of five rows	18	42.55	6.27	14.73
Three-row Plot (Interior rows)	18	43.13	5.04	11.68
Five-row Plot	18	42.55	4.86	11.41

In the wheat variety test of 1920 the check variety was Fultz, which was seeded at the rate of six pecks per acre in every seventh plot. The results of interest in this connection are shown in Table 22.

TABLE 22.—YIELD AND VARIABILITY OF CHECKS PLOTS.
Single-row, Three-row, and Five-row.—Wheat Variety Test 1920

Size of plot	Number of plots	Yield per acre	Standard deviation	
		bu.	bu.	%
Single-row				
Row 1	80	20.74	6.58	31.72
Row 2	80	17.28	5.02	29.05
Row 3	80	18.34	4.50	24.52
Row 4	80	17.29	5.10	29.48
Row 5	80	19.37	6.00	30.97
Mean of three interior rows	80	17.64	4.87	27.68
Mean of five rows	80	18.60	5.44	29.15
Three-row Plot (Interior rows)	80	17.64	4.43	25.11
Five-row Plot	80	18.63	4.77	25.60

Again the single rows are distinctly more variable than the 3-row plot, in this case to the extent of 10 per cent. The 5-row and the 3-row plots are about equally variable, the slight advantage in this case being in favor of the latter.

To summarize, it is evident that the protected 3-row plot is somewhat less subject to plot variability than the protected single-row, but the relative value of the 5-row plot harvested entire and the same plot harvested as a protected 3-row block is not clear. Some further comparison of these two methods was made in 1921. The variability of the check plots in both the wheat and oats tests was computed as protected 3-row and as unprotected 5-row plots. In the wheat tests the check variety was Poole, seeded at 5 pecks per acre in every seventh plot in the variety test, and in every sixth plot in the mixture test. In the oats tests the check variety was Kherson, seeded at 10 pecks per acre in every sixth plot. The results are shown in Table 23.

TABLE 23.—YIELD AND VARIABILITY OF CHECK PLOTS.
Three-row and Five-row.—Wheat and Oats Tests, 1921.

Size of plot	Number of plots	Yield per acre	Standard deviation	
		bu.	bu.	%
Wheat Variety Test				
Three-row Plots (Interior rows)	80	14.89	2.16	14.50
Five-row Plots	80	13.98	1.90	13.61
Wheat Mixture Test				
Three-row Plots (Interior rows)	30	15.48	3.25	20.98
Five-row Plots	30	15.78	3.55	22.49
Oats Variety and Strain Tests				
Three-row Plots (Interior rows)	120	37.95	4.61	12.15
Five-row Plots	120	38.37	4.70	12.25

In no case are the differences very great. The variability of 3-row blocks is slightly greater in the mixture test and that of 5-row blocks in the variety test of wheat. There is practically no difference between the two in the oats tests.

Apparently there is no constant material gain in plot uniformity obtained by the inclusion of the border rows of the 5-row plot, even though the size of the plot is materially increased by this procedure. Even if variability were decreased by their inclusion, the practice would be of doubtful value in most tests, for the reasons given in the last section; but with practically no decrease in variability there is left no

reason for the harvesting of these rows. They are not wasted because they are not harvested, for they serve a valuable purpose; the waste would be involved rather in harvesting them, for the added labor and expense would contribute nothing to the accuracy of the experiment.

Although protected 3-row plots are less variable than protected single-row plots, they are not necessarily preferable. Three protected 3-row plots require the same area as five protected single-row plots, and the harvesting of almost twice as large a crop (nine rows in the first case for every five in the second). If the mean yield of five single rows has as low a probable error as the mean yield of three 3-row plots, the protected single-row plot will ordinarily be preferable, because of the reduction of labor in harvesting and threshing. When the standard deviation of the check plot yields is known, the probable error of the mean of any number of replicate plots can be computed and the number of replications for any given degree of accuracy determined. If single-row plots were 29 per cent more variable than 3-row plots, the probable errors of the mean of three 3-row plots and of five single-row plots would be equal, since the probable error of the mean is equal to the probable error of a single determination divided by the square root of the number of determinations, and since the square root of 5 is 29 per cent greater than the square root of 3. In the cases herein cited the advantage of the 3-row plots was considerably less than 29 per cent in every case, and we may confidently expect therefore that protected single-row plots repeated five times will be less variable than protected three-row plots repeated three times, which would require the same area and more labor.

Some further evidence on the relative variability of the protected 3-row plot and the unprotected 5-row plot, or, in other words, of 5-row plots, harvested with and without their border rows, may be obtained from the yields of the tested varieties and strains. Since the number of replications of each strain is small, average deviations are given instead of standard deviations. The inclusion of border rows in the 5-row plots should not increase variability, since the adjacent varieties are the same in each series, and the competitive effect should be no more variable than would be that of the same variety. A clear-cut comparison of 5-row and 3-row plots is therfore available in this case. In the case of the check plots this comparison was somewhat obscured by the competitive effect of different varieties on the border rows, which might be expected to increase variability and thus to conceal a possible advantage of the 5-row plot.

The average variability of 3-row and 5-row plots in the strains tested in these experiments is shown in Table 24. In each case the

figure given is the mean of the average variabilities determined for all of the varieties or strains in the experiment.

TABLE 24.— YIELD AND VARIABILITY OF TEST PLOTS.
Three-row and Five-row.

Test	Season	Number of varieties	Number of Replications	Three-row Plots		Five-row Plots	
				Yield bu. per acre	Average Deviation %	Yield bu. per acre	Average Deviation %
Barley varieties	1919	27	3	22.06	15.35	21.95	15.44
Oats strains	1919	15	4	50.07	5.96	50.20	5.10
Wheat varieties	1920	96	4	13.39	24.27	13.78	24.36
Wheat varieties	1921	96	4	15.42	10.30	15.57	9.74
Wheat mixtures	1921	30	4	17.62	9.84	18.15	10.03
Oats varieties	1921	32	4	29.85	10.86	30.70	10.14
Oats strains	1921	64	4	28.40	10.82	28.63	10.58

There is no consistent difference in variability between the 3-row plots and the 5-row plots. In some cases the former are more variable; in others the latter; and in no case is the difference in variability great. These results are contrary to the general impression that variability decreases with increase in size of plots. Apparently, in tests of this kind, the 3-row plot is large enough to give a fair sample and nothing is gained by adding the other two rows. When it is considered that the addition of these two rows undoubtedly introduces systematic error from competition to a greater or less extent, and involves a very considerable increase in the labor of harvesting and threshing, there remains little doubt that the border rows of 5-row plots are best discarded in experiments of this sort.

Replication of Plots.—It is generally considered that the error from soil variability may be reduced to any desired point by replication in sufficient degree. For any given degree of precision the number of replications required is dependent on the variability of the replicate plots. When every plot in a single-row test is provided with two border rows the area required for the test is tripled, the replicate plots are separated more widely, and variability is usually increased, since the range of soil variability will usually be greater when a larger area is included.

The removal of border effect from the rows harvested for yield may in some cases reduce variability more than enough to balance this increase, but when the unprotected single rows are grown in the same order in each series, variability will not be much affected by competition. as before stated. Consequently more replications of single-row

plots protected by borders than of the single-row plots not so protected may actually be required for a given degree of plot variability. Similarly, more replications may be required in a test of a large number of strains than in a test of a small number, as Montgomery[14] has suggested.

The number of replications required may be determined with a fair degree of accuracy from the variability of the check plots. The variability of the check plots in parts of the large fields used as compared with the variability of the check plots in the whole fields shows the importance of this point. In Table 25 are given the standard de-

TABLE 25.—RELATION OF PLOT VARIABILITY TO SIZE OF EXPERIMENT FIELD. Check Plots in Wheat Variety Test 1920.

Size of field	No. of Plots	Yield bu. per acre	Standard deviation bu.	Standard deviation %
Four ranges (1st)*	20	14.79	3.789	25.62
Four ranges (2nd)	20	18.35	4.073	22.20
Four ranges (3rd)	20	16.67	3.659	21.94
Four ranges (4th)	20	20.74	3.876	18.69
Mean	20	17.64	3.849	22.11
Eight ranges (1st)	40	16.57	4.316	26.05
Eight ranges (2nd)	40	18.71	4.285	22.90
Mean	40	17.64	4.302	24.48
Sixteen ranges	80	17.64	4.430	25.11

*The four-range and eight-range sections are in order from west to east.

viations of the yields of the check plots in the wheat variety test of 1920. The yields of the three interior rows of the check plots were used in computing these constants.

Twenty-four varieties could have been replicated four times in the four ranges comprising any quarter of the field. As the probable error of a single plot yield is 14.92 per cent we may conclude that the probable error of the mean of four such yields would be about 7.46 per cent. But when 96 varieties must be tested, as they were in this test, four replications require 16 ranges, and the probable error of the mean yield becomes 8.47 per cent. A degree of precision which could be attained with four replications in a test covering four ranges could hardly be attained with five replications in a test covering sixteen ranges.

Corresponding data for the wheat variety test of 1921 are given in Table 26. Although the variability in this experiment was much lower, the relative variability of large and small experiment fields was

TABLE 26.—RELATION OF PLOT VARIABILITY TO SIZE OF EXPERIMENT FIELD. Check Plots in Wheat Variety Test 1921.

Size of field	No. of Plots	Yield bu. per acre	Standard Deviation bu.	%
Four ranges (1st)*	16	15.78	1.584	10.04
Four ranges (2nd)	16	15.48	1.586	10.25
Four ranges (3rd)	16	15.28	2.099	13.74
Rour ranges (4th)	16	13.01	2.091	16.07
Mean	16	14.89	1.840	12.53
Eight ranges (1st)	32	15.63	1.592	10.19
Eight ranges (2nd)	32	14.14	2.383	16.85
Mean	32	14.89	1.988	13.52
Sixteen ranges	64	14.89	2.159	14.50

*The four-range and eight-range sections are in order from west to east.

similar. Again the degree of accuracy obtained with four replications in four ranges would have been unattainable with five replications in 16 ranges.

The oats variety test and strain test in 1921 were contiguous, occupying 24 ranges, with 120 check plots of Kherson oats, or one in every sixth plot. The variability of these check plots in sections of

TABLE 27.—RELATION OF PLOT VARIABILITY TO SIZE OF EXPERIMENT FIELD. Check Plots in Oats Variety and Strain Test, 1921.

Size of field	No. of plots	Yield bu. per acre	Standard deviation bu.	%
Four ranges (1st)	20	35.81	4.75	13.26
Four ranges (2nd)	20	34.95	2.90	8.30
Four ranges (3rd)	20	38.14	4.21	11.04
Four ranges (4th)	20	39.60	4.66	11.77
Four ranges (5th)	20	38.91	4.14	10.65
Four ranges (6th)	20	40.31	4.14	10.27
Mean	20	37.95	4.13	10.88
Eight ranges (1st)	40	35.38	3.96	11.19
Eight ranges (2nd)	40	38.87	4.50	11.58
Eight ranges (3rd)	40	39.60	4.21	10.62
Mean	40	37.95	4.22	11.13
Twelve ranges (1st)	60	36.30	4.25	11.71
Twelve ranges (2nd)	60	39.60	4.36	11.01
Mean	60	37.95	4.31	11.36
Twenty-four ranges	120	37.95	4.61	12.15

four, eight, and twelve ranges, and in the whole field of 24 ranges, is shown in Table 27.

The variability of the whole field of 24 ranges was 12 per cent greater than the average variability of sections of four ranges each. In this case again, five replications in the larger field would have given less accurate results than four replications in the smaller.

In each of the cases cited above a steady increase in variability is apparent as the size of the experiment field is increased. It is obvious that the substitution of 3-row plots with discarded borders for single rows will result in greater variability, and will require increased replication for the same degree of accuracy.

From the foregoing statements it will be clear that the number of replications necessary for a given degree of accuracy may vary considerably with conditions. The number to be used in any specific experiment should be determined from the variability of the field in question and the degree of accuracy required. The variability of the check plots is usually considered a measure of the variability of the field. But when the number of replications to be used or the extent of experimental error is determined from the variability of the check plots, it is assumed that the variability of different varieties of the same crop is approximately the same under the same conditions. This of course is not strictly true. The yield of two varieties may be determined by very different factors, as has been stated, and their relative variability may also be quite different. The variability of 120 plots

TABLE 28.—SOIL HETEROGENEITY OF AN EXPERIMENT FIELD AS DETERMINED FROM YIELDS OF TWO CHECK VARIETIES.
Oats Variety and Strain Tests. 1921.

Check variety	Number of plots	Average yield	Standard deviation		Probable error of a single yield determination	
		bu.	bu.	%	bu.	%
Kherson	120	37.95	4.61	12.15	3.11	8.20
Red Rustproof	120	22.44	3.99	17.78	2.69	11.99

each of Kherson and Red Rustproof oats, grown side by side as check plots in the oats variety and strain test of 1921, illustrate the possibility of a serious error in the use of the standard deviation of check plots as a measure of the variability of an experiment field. These determinations are shown in Table 28.

The field would have been considered decidedly less variable if Kherson had been used as the check variety than if Red Rustproof had

been used. Both of these are standard recommended varieties for the region, though they differ decidedly in their characteristics. Both have been used frequently as check varieties at the Missouri station in past seasons. From the variability of the Kherson check plots the mean yield of four replicate plots in this experiment would be considered to have a probable error of 4.10 per cent; from the Red Rustproof plots the same determination would be given a probable error of 6.00 per cent. A degree of precision for which we would assume four replications necessary, judging from the Kherson check, would require nine replications according to the yields of the Red Rustproof check.

The importance of choosing a check variety typical of the varieties tested, if its variability is to be considered a criterion of the variability of the field, is obvious. Whether it is possble to choose a "typical variety" for the purpose, in the case of ordinary variety tests, remains to be seen.

ADJUSTMENT OF YIELDS BY MEANS OF CHECK PLOTS

Adjustment of plot yields by the use of check plots has been a common practice in field experiments during recent years. It is recognized that no experiment field is perfectly uniform in productivity, and the attempt is made, by means of the check plot adjustment, to compensate the varieties or treatments which chance to be located on the less productive plots for the resulting loss in yield. The common method, in variety tests, is to distribute over the field, as frequently as practicable, check plots planted to the same variety and similarly handled in every way. The variation in yield among these check plots is then considered a measure of the productivity of the soil. By various methods, differing only in detail, the yields of the test plots in parts of the field giving high check yields are reduced, and those of test plots in parts giving low check yields are increased, in proportion to the productivity of the soil, as indicated by the yields of neighboring check plots.

Previous Investigation.—Several investigations of the effect of such adjustment on the variability of replicate plots have been reported. The majority of these have been conducted in connection with experiments of the type discussed in the preceding section, in which uniformly handled fields have been harvested in small sections. Certain of these sections, or plots, have been considered check plots, and on the basis of their yields the yields of the remaining plots have been

adjusted. The reduction of variability of the adjusted plot yields is the measure of the efficiency of the method.

Morgan[15] reports an experiment of this sort, in which 63 plots, planted first to wheat and then to fodder corn, in the same season, were used. The variability of the plot yields was steadily reduced as the number of check plots was increased.

In a similar experiment reported by Lyon[11], in which 37 replicate 1/100 acre plots of corn were harvested, the use of checks in every second or third plot was found to reduce variability, but they were of little value when farther apart.

Montgomery[14] states that alternating check plots with test plots gives a high degree of accuracy, but the total number of plots required when this method is used is greater than when the same degree of accuracy is attained by the use of replication.

Kiesselbach[5] reports a comprehensive trial of three methods of adjusting yields by means of check plots in a uniform field of 207 1/30-acre plots of Kherson oats. The effect on plot variability is shown in Table 29.

TABLE 29.—EFFECT ON PLOT VARIABILITY OF ADJUSTING YIELDS BY CHECK PLOTS (KIESSELBACH).

Method of adjustment	Coefficient of variability	
	Actual yields	Adjusted yields
Alternate check plots. Correction based on average of two adjacent checks	7.85	7.01
Checks every third plot. Correction based on one adjacent check plot	7.79	7.35
Checks every third plot. Correction by progressive method, based on two nearest checks	7.87	6.57

From these results Kiesselbach concludes "The yield of systematically distributed check plats cannot be regarded as a reliable measure for correcting and establishing correct theoretical or normal yields for the intervening plats."

It should be noted at this point that even if adjustment by check yields were found invariably effective in experiments of this sort,

its value in ordinary variety testing would not be definitely established. The practice involves not only the assumption that the yields of the check plots are a fair indication of the productivity of the intervening plots for the check variety, but the further assumption that different varieties respond similarly to differing growing conditions. Adjustment of yields should therefore give better results in such experiments as those cited above than it could be expected to give in actual variety tests.

This point is well illustrated by observations reported by Salmon[16]. Two varieties of barley, Gatami and Odessa, were grown side by side in fiftieth-acre plots in five distributed portions of a field. Gatami gave an average yield of 18.3 bushels per acre, with quite uniform yields in the five plots, as evidenced by their probable error of 0.68 bushel, while Odessa yielded 13.3 bushels per acre in the first plot, 6.35 bushels per acre in the second, and a negligible yield in the other three. Obviously the adjustment of the yield of either of these varieties on the basis of the other variety as a check, would enormously increase rather than decrease the experimental error. As Salmon points out, an error similar in kind though less in degree may occur commonly in variety tests, when the yields of varieties are determined by different limiting factors. And if this is generally the case, adjustment by check yields will be of doubtful value, even if it were found to eliminate variability completely in uniform plot tests.

There is a growing tendency, consequently, to discontinue the use of check plots for adjusting yields in variety tests, and to use them only to measure soil variability and to indicate the degree of error in yield determinations of the tested varieties. Adjustment of yields has never been as common in preliminary tests as in tests on larger plots, principally because of the great amount of computation necessary in adjusting the yields of ten or twenty replicate rod-rows of a large number of varieties, and because the yield of a single rod-row, exposed to varying competition and materially affected by small mechanical errors, is at best a very unreliable measure of productivity on which to base the adjustment of the yields of several other plots.

Experimental Results.—It would of course be very desirable to use check plots for reducing plot variability, if the method could be relied on, because of the economy of the practice. The only certain method of reducing plot variability is by means of replication, and it may be considered a fairly general rule that the variability of plots on a given field, as measured by the standard deviation or the probable error, will in general be reduced by replication in proportion to the square root of the number of replications. In other words, the

variability of the mean of 16 replicate plots will be about half that of the mean of 4 replicate plots. Now the maximum use of check plots, that is, the practice of alternating check plots and test plots, requires the same land and labor as would be required by doubling the number of replications, if no check plots were used. As doubling the number of replications will in general give a standard deviation about equal to the original standard deviation divided by the square root of 2, it will reduce variability about 30 % $\left(\frac{1}{\sqrt{2}} = .7071\right)$. If alternating with check plots will consistently reduce variability more than 30 per cent it will be generally a more economical way to control error. Similarly, the use of check plots in every third plot requires as much land as would be required by increasing the number of replications by 50 per cent (using three replications instead of two, or fifteen instead of ten). From this relation the reduction of variability necessary if this practice is to equal replication in effectiveness can be easily computed. Such determinations for check plots at various intervals are shown in Table 30.

TABLE 30.—REDUCTION OF VARIABILITY BY THE USE OF CHECK PLOTS EQUIVALENT TO THAT PROBABLY ATTAINABLE WITH THE SAME NUMBER OF PLOTS BY REPLICATION.

Distribution of check plots	Equivalent increase in number of replications %	Reduction in standard deviation to be expected by such increase in replication %
Alternate plots	100.00	29.29
Every third plot	50.00	18.35
Every fourth plot	33.33	13.50
Every fifth plot	25.00	10.55
Every sixth plot	20.00	8.71
Every seventh plot	16.67	7.41
Every eighth plot	14.29	6.47
Every ninth plot	12.50	5.75
Every tenth plot	11.11	5.12

If protected single-row or 3-row plots are used in preliminary experiments a more reliable measure of soil productivity is available, and consequently the adjustment of yields is more likely to be of value, than when unprotected single-row plots are used. By the use of planting plans of the sort employed in these experiments, it is pos-

sible to adjust the yields by a somewhat shortened method. If adjustment of yield is effective in reducing plot variability in this sort of test it can be accomplished with but little increase in labor. In each of the tests reported in this paper a trial of the effectiveness of adjusting yields by means of check plots was made, the criterion of accuracy being in each case the variability of the yields of the replicate plots of each variety. Since the number of replicate plots was only three or four the average deviation was determined instead of the standard deviation.

Method Used in Adjusting Yields.—The method employed in adjusting yields may be described as follows: The average yield of all check plots and the relative yield of each check plot in terms of this average (that is, the quotient obtained by dividing the yield of the individual check plot by the average yield of all check plots) were determined. The relative yield of each check plot, expressed in percentage of the mean check yield, is designated hereafter as the "plot value" of that check plot. When the average yield of all check plots is 25 bushels per acre, the plot value of a check plot yielding 30 bushels per acre is 120 per cent—in other words it is 20 per cent more productive than the average. Now assuming gradual change in the productivity of the soil between check plots, each test plot is assigned a plot value by interpolation. The adjusted yield of each plot is then determined by dividing the actual yield by the plot value.

The short method for adjusting yields, referred to above, is based on the fact that the varieties occur in the same order in each series. Thus in the field diagrammed in figure 1, the following sequence of plots occurs in each of the four series:

ck 1 17 33 49 65 81 ck

Now if the average yield of the four check plots adjoining variety 1, and the average yield of the four check plots adjoining variety 81 are each given a plot value, corresponding plot values for the mean yields of varieties 1, 17, 33, 49, 65, and 81 may be interpolated, and the mean yields may be adjusted in one operation. The same method may be used, of course, regardless of the number of replications. The result will not be exactly the same as that of averaging the adjusted yields determined individually, but will in most cases approximate it closely, the slight difference being caused by the disproportion of yield and plot value in the plots averaged. It is doubtful that either method is consistently more accurate than the other.

When the check plot yield is used in the adjustment of the yields of other plots it is of course essential that it should be a reliable determination, not unduly affected by factors not affecting the neighbor-

ing plots. For example if the yield of a check plot is reduced 20 per cent by a poor stand, the adjusted yields of neighboring plots will be increased to the same extent as if the check plot yield had been low because of poor soil, and will consequently be considerably higher than they should be. It is important therefore that conditions be made as favorable as possible for accurate yield testing when this method is used. One cause for poor results in the adjustment of yield in some of the experiments reported in this paper was failure to protect the outside strip of check plots by means of border rows, in a few of the tests, be-

TABLE 31.—RELATIVE VARIABILITY OF ACTUAL AND ADJUSTED YIELDS. Average Deviation in Percentage of Yield.—Barley Variety Test 1919.

Planting number	Variety	Average deviation: Actual yields, 3 interior rows %	Actual yields, 5 rows %	Adjusted yields, 3 interior rows %	Adjusted yields, 5 rows %
1	Hanna 906	19.81	17.82	13.15	10.80
2	Steigum 907	15.17	18.79	13.48	8.40
3	Luth 908	29.97	28.17	5.51	4.62
4	Eagle 913	26.14	29.79	9.71	12.98
6	Servian 915	18.37	17.97	7.36	5.59
7	Odessa 916	2.31	4.33	23.99	17.01
8	Lion 923	14.65	12.10	11.37	11.03
10	Horn 926	4.08	2.00	16.45	12.74
11	Odessa 927	13.62	9.16	21.62	13.76
12	Summit 929	5.28	6.45	14.23	11.59
13	Mariout 932	11.02	11.57	18.68	14.31
14	Odessa 934	13.73	13.91	11.18	10.31
15	Peruvian 935	13.25	17.87	12.42	16.82
16	Trebi 936	11.27	12.53	18.78	18.28
18	Oderbrucker 940	10.77	14.46	13.60	15.98
19	Frankish 953	20.53	19.65	22.63	18.49
20	Manchuria 956	6.88	6.33	13.89	10.68
21	Oderbrucker 957	17.88	13.62	1.97	3.27
22	Manchuria x Champion of Vermont	39.47	39.19	21.93	20.35
23	Luth 972	16.77	18.61	7.05	7.48
24	Red River 973	13.94	11.02	12.37	12.33
25	Featherston 1118	21.40	20.89	8.47	13.39
26	Featherston 1119	16.59	15.25	4.78	12.26
27	Featherston 1120	15.91	13.64	2.48	6.44
28	Hanna x Champion of Vermont 1121	16.00	16.81	28.36	28.50
29	Manchuria 1125	6.79	14.42	7.78	1.55
30	Malting 1129	12.86	10.40	5.40	9.02
	Mean	15.35	15.44	12.91	12.15

cause of lack of space. The check plots growing on the border of the field were materially reduced in yield, in some cases, notably the oats strain test of 1919 and the wheat variety test of 1921. In these cases the variability of the actual and adjusted yields has been computed both for all series and for the remaining series when the one affected by an unreliable check is discarded.

Relative Variability of Actual and Adjusted Yields.—The relative variability of actual and adjusted yields of both 3-row and 5-row plots in the barley variety test is shown in Table 31. In this test there were three replications, and the check variety was Oderbrucker, in every

TABLE 32.—RELATIVE VARIABILITY OF ACTUAL AND ADJUSTED YIELDS. Average Deviation in Percentage of Yield Oats Variety Test 1919.

Planting number	Variety	Average Deviation 3 Series (3 interior rows) Actual yields %	Adjusted yields %	4 Series (3 interior rows) Actual yields %	Adjusted yields %
1	A. sterilis nigra	4.32	1.46	9.18	5.02
2	Black Mesdag	9.03	9.69	7.29	12.90
3	C. I. 602	13.72	16.00	16.30	13.63
3	C. I. 603	4.72	3.09	5.84	3.88
5	C. I. 620	4.73	10.14	11.24	13.67
6	Early Champion	18.63	15.18	14.97	14.65
7	Early Gothland	14.20	4.67	11.55	4.18
8	Garton 473	5.99	6.25	8.42	9.42
9	Garton 585	14.08	19.44	16.92	19.95
10	Golden Giant	9.44	14.31	14.40	15.09
11	Irish Victor	9.69	3.29	7.72	16.40
12	Japanese Selection	6.87	4.71	11.85	5.20
13	June	18.37	11.19	17.53	10.37
14	Kherson Selection	17.01	9.20	15.06	20.36
15	Fulghum	9.69	11.36	13.06	17.32
16	Lincoln	21.07	12.54	16.56	11.83
17	Monarch	6.12	4.55	9.06	33.36
18	North Finnish	8.69	5.17	7.84	27.03
19	Scottish Chief	5.05	4.28	5.10	15.42
20	Sparrow bill (Missouri)	10.98	10.82	12.38	13.15
21	Sparrow bill (Cornell)	4.45	3.25	12.11	3.85
22	Tobolsk 1	6.17	3.85	13.92	5.38
23	Tobolsk 2	11.56	9.24	20.35	13.96
24	White Tartar	10.94	4.75	9.51	4.54
	Mean	10.23	8.27	12.01	12.94

sixth plot. As a result of the adjustment of yields, the average deviation of 3-row plots was reduced from 15.35 per cent to 12.91 per cent, a reduction of 16 per cent, and that of 5-row plots from 15.44 per cent to 12.15 per cent, a reduction of 21 per cent.

The relative variability of actual and adjusted yields in the oats variety test of 1919 is shown in Table 32. In this field the check, Red Rustproof, was in every ninth plot. When the series affected by the faulty check yields of the border plots is included the variability of the adjusted yields is slightly higher than that of the actual yields, but when this series is discarded the average variability as measured by the mean deviation is reduced 19 per cent.

It might be expected that the oats strains grown on the same field would show a greater reduction of variability than the varieties, since practically all of them were of the same variety as the check, and since

TABLE 33.—RELATIVE VARIABILITY OF ACTUAL AND ADJUSTED YIELDS.
Average Deviation in Percentage of Yield.
Oats Strains Test 1919.

Planting number	Accession number	Average deviation			
		Actual yields		Adjusted yields	
		3 interior rows %	5 rows %	3 interior rows %	5 rows %
1	0119	10.30	7.75	11.22	8.81
2	0120	4.70	6.58	3.01	1.76
3	0121*	5.76	3.25	4.57	4.14
4	0122	4.62	3.52	6.46	3.82
5	0123	9.91	8.25	11.47	9.62
6	0125	3.18	3.34	5.39	6.60
7	0126	7.62	5.95	10.56	16.58
8	0127*	6.76	5.09	6.92	9.85
9	0124*	6.13	6.34	4.92	4.59
10	0133	7.07	4.77	3.92	5.36
11	0128	4.17	3.56	3.58	3.36
12	0129	5.02	7.07	5.94	6.35
13	0130	4.20	2.62	6.74	9.72
14	0131	2.59	2.59	4.98	2.94
15	0132	7.38	5.81	12.38	12.08
	Mean	5.96	5.10	6.80	7.04

* Not taxonomically Red Rustproof.

the check plots were more frequent, being in every sixth plot. The results of adjusting yields in this test, both for protected 3-row plots and for unprotected 5-row plots in four series are shown in Table 33. Contrary to expectation, the variability was not reduced by adjustment

TABLE 34.—RELATIVE VARIABILITY OF ACTUAL AND ADJUSTED YIELDS.
Average Deviation in Percentage of Yield.—Wheat Variety Test 1920.

Planting Number	Variety	Average Deviation Actual yield 3 interior rows, %	Actual yield 5 rows %	Adjusted yield 3 interior rows, %	Adjusted yield 5 rows %
1	Beechwood Hybrid No. 12	22.8	27.0	20.3	21.5
2	Beechwood Hybrid No. 81	27.0	26.3	13.9	15.7
3	Beechwood Hybrid No. 85	44.8	40.6	27.5	22.0
4	Beechwood Hybrid No. 87	52.1	49.0	38.5	30.6
5	Beechwood Hybrid No. 202	27.3	29.3	21.3	16.1
6	Beechwood Hybrid No. 207	24.2	28.4	18.3	18.2
7	C. I. 3808	24.8	24.8	14.8	10.7
8	C. I. 3846	14.5	13.0	18.3	11.5
9	C. I. 3872	17.9	24.1	6.5	8.8
10	C. I. 3980	19.2	22.0	9.3	9.0
11	C. I. 3988	13.2	14.0	8.8	6.4
12	C. I. 4004	25.6	21.7	13.5	6.1
13	Common Rye	10.1	10.9	15.4	18.2
14	Dawson's Golden Chaff	46.0	40.3	25.9	15.1
15	Dietz	37.1	38.4	13.4	14.4
16	Early Ripe	45.5	47.3	23.1	19.3
17	Early Ripe No. 26	17.9	15.2	7.6	9.2
18	Early Red Clawson	24.5	30.8	15.7	22.3
19	Farmers' Friend	26.7	28.0	11.2	12.3
20	Fulcaster	40.4	40.0	29.1	24.4
21	Fultz-Archias	26.8	29.6	22.9	20.1
22	Gold Coin	29.2	28.5	22.8	24.6
23	Greene County	23.1	28.3	27.7	21.5
24	Harvest King No. 7	26.7	27.2	12.0	10.3
25	Harvest Queen	21.4	24.0	18.2	14.1
26	Hickman	40.0	39.6	23.1	18.9
27	Illini Chief	14.7	14.5	7.7	9.8
28	Jones' Climax	12.0	9.9	5.5	4.0
29	Kanred	14.9	15.9	18.2	13.6
30	Kessinger	19.2	21.4	5.7	9.3
31	Kharkov	25.4	29.6	6.3	9.1
32	Leap's Prolific	27.4	28.4	11.2	13.1
33	Mediterranean No. 8	22.4	21.2	12.9	14.3
34	Michigan Amber	18.3	20.2	11.2	12.5
35	Michigan Amber (Indiana)	20.5	20.9	9.0	9.6
36	Michigan Amber No. 7	41.8	39.3	29.9	26.2
37	Michigan Amber No. 12	28.9	32.9	21.5	25.4
38	Michigan Wonder	33.8	36.2	21.8	21.4
39	Michigan Wonder No. 4	19.9	20.0	11.8	10.9
40	Michigan Wonder No. 8	29.2	29.4	12.2	12.3
41	Michigan Wonder No. 21	28.3	30.4	16.7	16.2
42	Michigan Wonder No. 53	45.8	42.6	31.3	26.9
43	Michigan Wonder No. 54	39.6	32.4	32.5	25.6
44	Michigan Wonder No. 83	19.5	21.1	13.8	12.9
45	Michigan Wonder No. 96	34.4	38.3	16.8	15.9
46	Michigan Wonder No. 103	35.8	36.2	15.2	13.9
47	Michigan Wonder No. 116	28.6	26.2	11.9	4.2
48	Michigan Wonder No. 130	33.2	33.2	14.2	13.7

Planting Number	Variety	Average Deviation Actual yield 3 interior rows, %	Actual yield 5 rows %	Adjusted yield 3 interior rows, %	Adjusted yield 5 rows %
50	Michigan Wonder No. 141	18.0	19.4	8.9	14.0
51	Michigan Wonder No. 155	23.9	21.7	11.5	14.6
52	Michigan Wonder No. 209	35.9	37.6	24.4	26.4
53	Michigan Wonder No. 211	28.8	31.7	17.1	18.4
54	Michigan Wonder No. 221	33.2	38.0	19.7	24.5
55	New York 123-32	17.1	15.1	3.8	2.2
56	Niagara	26.4	19.0	7.4	3.9
57	Nigger	23.7	23.8	27.1	21.3
58	Old Ironclad	29.1	27.6	13.4	12.7
59	Poole	21.1	18.3	16.2	12.4
60	Poole No. 3	21.1	21.2	16.0	12.9
61	Poole B-3	31.0	26.1	10.6	4.7
62	Portage	12.8	17.3	11.6	6.7
63	Pride of Indiana	30.1	33.7	16.4	13.2
64	Pride of Genessee	17.0	17.7	11.0	18.7
65	Reliable	8.4	7.4	7.8	11.4
66	Red Cross	11.8	10.6	6.4	5.9
67	Red May	19.8	25.2	23.8	24.8
68	Red Rock (Indiana)	15.8	18.1	14.0	10.3
69	Red Rock (Michigan)	53.6	51.6	40.0	35.6
70	Red Wave	22.7	18.9	19.6	16.2
71	Rochester Red	20.8	18.3	14.0	10.0
72	Rosen Rye	17.4	18.6	2.7	5.4
73	S. P. I. 11616	25.3	16.2	38.7	24.3
74	S. P. I. 26012	10.4	14.2	7.6	6.5
75	S. P. I. 26013	11.8	12.3	9.3	9.9
76	S. P. I. 26014	10.1	10.9	4.6	2.6
77	S. P. I. 26015	12.4	16.8	14.7	10.0
78	S. P. I. 26017	22.5	22.4	7.5	7.4
79	S. P. I. 26018	32.6	33.8	11.2	10.9
80	S. P. I. 26019	26.6	29.1	14.1	13.9
81	S. P. I. 26022	15.3	14.2	10.0	11.8
82	S. P. I. 26023	27.0	28.0	24.5	30.2
83	S. P. I. 26025	16.4	14.5	9.2	9.7
84	S. P. I. 26029	16.7	14.1	7.5	8.7
85	S. P. I. 26085	22.1	15.3	8.8	10.0
86	Treadwell	23.8	14.2	11.0	11.8
87	Valley	16.9	16.7	12.1	11.5
88	Velvet Chaff No. 2	28.3	27.3	14.0	12.6
89	Valvet Chaff No. 8	13.3	15.1	27.1	14.4
90	Ziegler Fly-Proof	17.2	17.4	5.3	8.1
91	13D-4a	15.8	15.9	13.2	11.1
92	37a-4	13.0	15.1	9.4	5.4
93	Fulcaster (Co-op)	19.1	20.9	6.3	4.8
94	Fultz (Co-op)	26.2	26.2	15.9	10.8
95	Kanred (Co-op)	15.9	14.9	16.2	19.7
96	Poole (Co-op)	15.9	16.7	7.7	10.5

of yield. A possible explanation is the extremely low variability of the actual yields, indicating that the field, which was quite small, was relatively uniform. Any gain in uniformity from a check adjustment of yields would of course be expected to be greater in highly variable than in more uniform fields. The relative uniformity of this field is indicated not only by the low mean deviation of the test plots, but also by the low standard deviation of the check plots, which was only 11.68 per cent, as compared with a standard deviation of 22.59 per cent in the check plots of the adjoining oats variety test.

The effect of adjusting yields on the variability of 3-row and 5-row plots in the wheat variety test of 1920 is shown in Table 34. In this test the check variety, Fultz, was grown in every seventh plot. There were four series of the ninety-six varieties.

The reduction in variability was very marked, being 37 per cent for 3-row plots and 42 per cent for 5-row plots. The variability of almost every variety was reduced, and the reliability of the results was undoubtedly much increased.

The wheat variety test of 1921, occupying an equal area on a neighboring field, and with similar varieties and the same planting plan, gave decidedly different results. In this field the check variety was Poole. Several check plots on the border were abnormal, and the computations are therefore given both for three series and for four, the series affected by the abnormal check yields being discarded in the former case. The relative variability of actual and adjusted yields is shown in Table 35.

Although the check yields are somewhat less variable for three series than for four, the adjustment was not effective in either case in reducing variability. The adjusted yields are 10 per cent more variable than the actual yields for the three series and 34 per cent higher for the four.

Similar results were obtained in the wheat mixture test of the same season, in which several of the same varieties were included, and the same check variety was used. In this test the check variety was in every sixth plot, and four replications were used. The results of adjusting yields are shown in Table 36. Variability was increased from 9.84 per cent to 13.81 per cent, an increase of 40 per cent. Thus the results of adjusting yields of wheat varieties in 1921 are directly contrary to the results of the same practice in 1920.

Difference in Results Obtained by Adjustment with Different Check Varieties.—In the oats variety and strain tests of 1921, two check varieties, Kherson and Red Rustproof, were grown. In these tests 96 strains were included, 32 of Kherson, 32 of Red Rustproof, and

TABLE 35.—RELATIVE VARIABILITY OF ACTUAL AND ADJUSTED YIELDS.
Average Deviation in Percentage of Yield.—Wheat Variety Test 1921.

Planting number	Variety	Average deviation 3 Series (3 interior rows) Actual yields %	Average deviation 3 Series (3 interior rows) Adjusted yields %	Average deviation 4 Series (3 interior rows) Actual yields %	Average deviation 4 Series (3 interior rows) Adjusted yields %
1	Beechwood Hybrid No. 12	12.29	14.76	15.62	12.93
2	C. I. 3808	9.71	12.66	8.45	11.72
3	C. I. 3846	4.66	15.00	5.26	12.36
4	C. I. 3972	9.01	7.80	9.82	6.01
5	C. I. 3980	13.68	13.84	14.90	12.93
6	C. I. 4004	6.84	5.49	5.52	6.32
7	Common Rye	12.86	8.11	13.36	6.75
8	Dietz	23.41	4.61	18.04	17.68
9	Defiance	10.19	17.99	10.52	17.45
10	Early Ripe	13.18	5.76	13.81	15.62
11	Early Ripe No. 26	3.44	9.81	6.00	8.10
12	Early Red Clawson	9.45	8.11	16.64	6.27
13	Farmers' Friend	15.56	23.11	12.91	18.84
14	Fulcaster	16.64	18.71	14.17	17.13
15	Fulcaster 1-y	9.06	18.33	8.56	20.00
16	Fulcaster 8-y	26.03	12.17	20.79	11.73
17	Fulcaster Co-op	4.44	4.49	8.77	5.61
18	Fulcaster Holmes	18.10	20.22	16.15	15.11
19	Fulcaster Blazier	14.06	11.50	11.34	10.69
20	Fulcaster Cowles	6.41	8.63	6.60	6.64
21	Fulcaster (Outl)	11.82	10.53	9.87	8.41
22	Fultz Co-op	5.05	6.63	6.48	5.47
23	Fultz Bayer	3.60	10.48	4.28	8.09
24	Fultz Gale	12.60	15.18	10.13	21.53
25	Fultz Check	2.59	8.42	2.11	17.33
26	Harvest Queen	6.78	4.23	6.49	13.29
27	Illini Chief	4.23	10.09	6.00	17.29
28	Jones Climax	5.10	7.58	7.69	2.55
29	Kanred	2.63	7.35	3.09	8.68
30	Kanred Co-op	1.75	5.69	5.76	7.08
31	Kessinger	11.14	21.19	8.91	18.64
32	Kharkov	17.01	4.05	17.85	12.96
33	Leap Prolific	5.20	3.38	5.19	3.26
34	Mediterranean No. 30	21.17	22.76	15.89	18.18
35	Mediterranean No. 31	9.09	10.28	7.48	9.20
36	Michigan Amber	9.21	4.96	8.56	4.43
37	Michigan Amber No. 7	7.54	12.33	7.51	10.50
38	Michigan Amber No. 8	6.84	4.54	8.13	4.14
39	Michigan Amber (Indiana)	8.51	8.83	8.75	7.37
40	Michigan Wonder	13.25	15.87	12.87	25.82
41	Michigan Wonder No. 4	7.62	12.13	6.82	18.22
42	Michigan Wonder No. 8	3.21	4.80	6.76	20.33
43	Michigan Wonder No. 21	5.98	1.09	6.78	18.69
44	Michigan Wonder No. 53	8.24	11.37	9.12	26.16
45	Michigan Wonder No. 54	14.96	16.99	13.20	15.50
46	Michigan Wonder No. 83	11.75	12.97	11.15	13.58
47	Michigan Wonder No. 96	6.62	15.12	5.29	11.34
48	Michigan Wonder No. 103	13.09	1.92	9.82	1.94
49	Michigan Wonder No. 116	6.46	4.00	9.17	4.92
50	Michigan Wonder No. 130	10.30	11.78	8.46	10.14
51	Michigan Wonder No. 140	9.26	10.15	7.72	9.15
52	Michigan Wonder No. 141	10.04	12.22	8.49	10.57
53	Michigan Wonder No. 155	4.44	4.00	6.15	8.49
54	Michigan Wonder No. 209	9.25	10.45	7.23	12.92
55	Michigan Wonder No. 211	6.09	6.41	4.70	5.90
56	Michigan Wonder No. 221	10.75	13.64	10.24	24.21
57	New York 123-32	6.33	14.90	6.61	28.54
58	Nigger	7.12	10.60	11.81	26.11
59	Old Ironclad	6.41	7.55	8.76	24.94
60	Poole	13.35	11.38	12.59	35.37
61	Poole B-3	11.92	14.67	14.83	16.63
62	Poole (Co-op)	12.08	15.29	9.80	11.95
63	Poole (Scott)	7.93	23.74	5.94	18.23
64	Poole (Corder)	12.79	7.26	10.34	6.21
65	Poole (Selection)	20.40	19.90	17.78	19.50
66.	Portage	15.40	16.47	12.27	13.76
67	Pride of Indiana	4.08	18.08	3.57	14.38
68	Red Hussar	22.89	16.67	18.32	13.80
69	Red Wave (Chesterfield)	22.78	11.14	19.93	8.50
70	Red Wave (McCauley)	23.75	17.34	19.62	16.89
71	Red Rock (Indiana)	5.99	4.73	7.22	9.33
72	Red Rock (Michigan)	5.54	11.09	4.28	23.54
73	Rochester Red	7.75	16.27	7.52	27.39
74	S. P. I. 26017	14.13	14.69	11.82	18.77
75	S. P. I. 26018	6.20	8.16	5.49	27.14
76	S. P. I. 26019	19.34	23.01	18.34	21.27
77	S. P. I. 25984	18.75	19.48	15.77	16.70
78	Beechwood Hybrid No. 207	13.44	11.55	11.45	10.08
79	S. P. I. 26022	6.57	7.54	4.93	8.44
80	S. P. I. 26023	16.09	15.14	19.21	18.34
81	S. P. I. 26025	4.96	7.20	12.23	14.62
82	S. P. I. 26029	14.44	15.12	11.18	13.44
83	S. P. I. 26085	7.50	10.14	9.92	9.77
84	Rosen Rye	9.25	12.56	7.67	11.35
85	Texas	10.56	8.86	8.21	12.04
86	Turkey	1.36	6.91	2.22	9.43
87	Turkey No. 24	20.00	10.63	16.05	10.25
88	Turkey (Kansas)	12.97	7.02	19.92	8.81
89	Velvet Chaff	6.90	16.58	12.52	17.63
90	Velvet Chaff No. 2	6.30	10.96	11.52	12.98
91	Velvet Chaff No. 8	2.50	5.59	5.22	18.53
92	Zeigler Fly-Proof	10.50	14.12	15.41	17.13
93	Poole No. 3	18.81	13.13	15.02	13.14
94	18D-4	6.26	4.88	7.51	4.27
95	Mediterranean No. 17	8.08	20.46	6.92	17.56
96	34B-2a	19.13	20.26	17.39	18.36
	Mean	10.45	11.52	10.30	13.77

TABLE. 36—RELATIVE VARIABILITY OF ACTUAL AND ADJUSTED YIELDS. Average Deviation in Percentage of Yield. Wheat Mixture Test 1921

Planting number	Variety	Average Deviation Actual yields (3 interior rows) %	Adjusted yields (3 interior rows) %
1	Fulcaster	9.67	16.90
2	Harvest Queen	9.35	21.47
3	Mixture No. 1	6.12	20.11
4	Michigan Wonder	7.88	20.51
5	Nigger	2.33	20.16
6	Michigan Wonder No. 31	4.93	13.86
7	Michigan Wonder No. 54	12.96	16.03
8	Mixture No. 2	15.38	17.86
9	Michigan Wonder No. 96	4.99	13.88
10	Michigan Wonder No. 209	5.30	14.83
11	Beechwood Hybrid No. 12	9.04	11.01
12	Beechwood Hybrid No. 85	14.98	15.49
13	Mixture No. 3.	16.76	10.47
14	Beechwood Hybrid No. 87	10.16	11.94
15	Beechwood Hybrid No. 207	20.80	11.81
16	Michigan Wonder No. 221	7.13	8.90
17	Kanred	10.09	12.86
18	Mixture No. 4	10.39	8.44
19	New York 123-32	16.73	12.09
20	Red Rock	14.04	10.68
21	Red Hussar	12.71	17.42
22	Turkey (Kansas)	17.32	13.74
23	Mixture No. 5	2.87	12.73
24	Michigan Amber	3.39	10.71
25	Nigger	4.09	10.47
26	Fulcaster (Co-op)	2.09	14.25
27	Fulcaster (Outl)	11.97	17.18
28	Mixture No. 6	11.19	7.75
29	Fulcaster (Blazier)	11.41	6.77
30	Fulcaster (Cowles)	9.09	14.11
	Mean	9.84	13.81

32 of other varieties. The yields were adjusted by means of each check variety separately, to determine the relation between the effectiveness of yield adjustment and the similarity of the check to the tested variety. The results of this adjustment on plot variability are shown in Tables 37 and 38.

The variability of the yields of the Red Rustproof strains was somewhat reduced (6 per cent) by adjustment according to the yields

TABLE 37.—RELATIVE VARIABILITY OF ACTUAL AND ADJUSTED YIELDS. Average Deviation in Percentage of Yield. Oats Variety Test 1921

Planting number	Variety	Average deviation: Actual yields (3 interior rows) %	Adjusted yields (3 interior rows) (Kherson) %	(Red Rustproof) %
65	Burt	10.22	11.54	11.00
66	Canadian	9.29	8.93	18.37
67	C. I. 603	9.21	4.94	13.89
68	Culberson	6.46	8.80	4.44
69	Danish Island	10.53	8.83	12.56
70	Early Dakota	9.33	7.96	11.45
71	Early Gothland	10.00	19.16	14.69
72	Garton 748	14.35	13.26	14.77
73	Green Russian	9.75	11.23	13.75
74	Irish Victor	9.43	8.07	15.99
75	Joanette	30.75	29.36	26.94
76	Fulghum 042	5.19	8.50	8.99
77	Monarch	4.76	6.36	8.54
78	Monarch Selection	2.89	5.74	11.55
79	Scottish Chief	10.95	15.01	8.66
80	Silvermine 050	11.24	9.88	9.21
81	Silvermine Selection	11.25	16.14	3.16
82	Sparrowbill (C)	23.93	23.03	25.23
83	Sterilis Selection	8.02	7.30	9.17
84	Storm King	11.68	13.94	13.15
85	Swedish Select 057	14.48	14.89	11.80
86	Fulghum 065	8.81	11.04	9.41
87	Fulghum 0113	22.19	11.18	15.85
88	Silvermine 0115	8.38	6.29	3.59
89	Silvermine 0117	6.90	8.95	9.69
90	Fulghum 0124	5.17	3.38	7.89
91	Fulghum 0145	9.81	8.63	15.66
92	Fulghum 0149	10.19	10.77	15.70
93	Fulghum 0151	10.85	12.71	10.80
94	Fulghum 0152	9.07	14.59	19.61
95	Silvermine 0165	5.63	11.32	4.62
96	Swedish Select 0165	16.74	14.02	8.74
	Mean	10.86	11.43	12.15

of the Red Rustproof check, but was slightly increased (2 per cent) when the Kherson check was used. On the other hand, the variability of the yields of the Kherson strains, though not reduced by either check, was increased only 4 per cent by the Kherson check, while it was increased 48 per cent by the Red Rustproof check. Neither check was effective in adjusting the yields of the other varieties, the Kherson

TABLE 38.—RELATIVE VARIABILITY OF ACTUAL AND ADJUSTED YIELDS. Average Deviation in Percentage of Yield.—Oats Strain Test 1921 (Red Rustproof and Kherson)

Red Rustproof strains					Kherson strains				
		Average deviation					Average deviation		
			Adjusted yields (3 interior rows)					Adjusted yields (3 interior rows)	
Planting Number....	Strain	Actual yields (3 interior rows)......	(Kherson)..	(Red Rustproof)	Planting Number..	Strain	Actual yields (3 interior rows)......	(Kherson)..	(Red Rustproof)
		%	%	%			%	%	%
1	066	18.13	15.48	13,04	2	023	15.80	7.59	12.93
3	067	12.89	14.19	11.36	4	040	3.86	5.59	10.45
5	068	23.14	21.34	12.47	6	041	9.50	5.82	4.07
7	069	21.55	20.54	11.70	8	052	3.46	2.83	10.49
9	072	14.29	12.26	10.34	10	053	6.26	5.97	10.14
11	074	12.18	17.23	13.94	12	079	11.49	9.91	10.20
13	075	13.40	18.28	18.80	14	080	1.72	7.02	13.20
15	0118	28.77	32.06	26.92	16	082	6.19	8.74	15.01
18	0119	10.32	13.47	13.62	17	083	5.31	5.88	9.26
20	0120	7.28	6.11	12.32	19	085	8.69	10.65	7.30
22	0122	17.16	12.32	14.20	21	086	11.73	7.45	8.45
24	0125	10.91	11.52	8.40	23	Mixture***	4.87	3.84	9.19
26	0126	10.41	10.24	4.66	25	088**	13.04	13.79	9.16
28	0128	14.48	17.36	2.76	27	089	4.69	6.77	12.89
30	0129	7.89	6.31	7.44	29	090	2.84	4.85	10.64
32	0130	7.99	11.78	9.17	31	091	12.46	14.67	10.84
33	0131	12.43	13.96	13.23	34	094	4.59	6.43	6.57
35	0132	17.77	14.67	12.11	36	095	4.36	4.96	14.62
37	0133	14.07	11.63	13.55	38	096	4.39	7.71	4.66
39	0134	29.91	30.37	29.50	40	097	5.53	6.97	11.80
41	0135	14.36	17.58	13.11	42	098	9.09	10.03	13.18
43	0136*	7.80	7.59	12.69	44	099	6.89	6.26	10.20
45	0141	12.58	13.30	11.11	46	0100	6.90	4.65	8.55
47	0163	2.70	1.82	14.28	48	0155	12.75	4.49	23.56
50	0169	21.95	17.79	23.03	49	0157	6.34	7.40	14.18
52	0181	9.95	7.62	9.69	51	0158	10.81	12.24	6.26
54	0182	26.12	21.76	20.84	53	0159	6.33	10.82	8.26
56	0183*	4.52	5.51	8.99	55	0160	4.98	6.12	12.52
58	0383	10.10	15.60	20.18	57	0161	5.55	9.19	9.27
60	0391	9.55	11,37	6.47	59	0162	11.28	13.38	9.47
62	0394	13.03	11.52	10.29	61	0167	2.65	3.37	4.41
64	0395	8.69	11.40	17.96	63	0174	10.74	8.96	15.67
Mean		14.47	14.70	13.55		Mean	7.16	7.44	10.59

* Not taxonomically Red Rustproof. Excluded from average.
** Not taxonomically Kherson. Excluded from average.
***Mixture of strains 082, 094, 0100, 0174.

check increasing their variability 7 per cent, and the Red Rustproof check 20 per cent. These results indicate the importance of using a check variety typical of the varieties tested, when adjustment of yields is to be made; and the danger of increasing rather than decreas-

ing error by this practice when the tested varieties are quite different in habit from the check variety.

The use of an unsuitable check variety not only increases the margin of error, but it may cause very deceptive comparative results. For example, the average yields of the Kherson strains 0155 and 0157, unadjusted and adjusted according to the yields of both check varieties, are shown below:

Method	Strain			
	0155		0157	
	Yield	Average Deviation	Yield	Average Deviation
Unadjusted	37.50	12.75	43.69	6.34
Adjusted by Kherson check	34.50	4.49	43.69	7.40
Adjusted by Red Rustproof check	39.94	23.56	39.38	14.18

The 17 per cent advantage in yield of strain 0157 is increased to 27 per cent by the Kherson adjustment, and since the variability of the replicate yields is reduced by the adjustment we may fairly assume that the latter is the more reliable figure. But when the Red Rustproof check is used for adjusting yields, the advantage of strain 0157 disappears entirely. The inaccuracy of the yields adjusted by Red Rustproof is indicated by the increase in plot variability resulting from this adjustment. Thus the adjustment of yields by means of check plots may mask considerable differences in yields between the varieties under test.

Although Kherson and Red Rustproof are decidedly different in type, both are commonly grown in Missouri, and both have been used frequently here as check varieties in oats variety tests. It is interesting

TABLE 39.—RELATIVE VARIABILITY OF ACTUAL AND ADJUSTED YIELDS OF KHERSON AND RED RUSTPROOF OATS, EACH IN 120 DISTRIBUTED PLOTS. Oats Variety and Strain Tests 1921.

Variety	Yield		Standard deviation	
	Actual	Adjusted	Actual yield %	Adjusted yield %
Kherson	37.95	39.04	12.15	20.79
Red Rustproof	22.44	22.80	17.78	19.92

to determine the effect on variability of adjusting the yields of the 120 plots of Kherson, on the basis of those of the 120 plots of Red Rustproof adjoining them, and those of the 120 plots of Red Rustproof, on the basis of the yields of the adjoining Kherson plots. In this adjustment the yield of each plot is divided by the plot value of the adjoining plot, and the method corresponds to method II used by Kiesselbach in the experiment cited above (see Table 29). The results of the yield adjustment are shown in Table 39.

The adjustment of plot yields by means of check plots of a variety distinctly different in type resulted in a decided increase in plot variability, even though the plot values used were determined in each case by the yield of the immediately adjacent plot. If the yields of the Kherson and the Red Rustproof plots had been perfectly accurate measures of the productivity of the soil, the plot values of the adjacent plots would have been almost the same in each of the 120 locations, and the adjustment of the yields of either variety by those of the other would have reduced variability almost to zero. Instead, variability was actually and very decidedly increased, because the sections of the field which gave relatively high yields of Kherson, gave relatively low yields of Red Rustproof, and vice versa, in many cases. In fact, there was very little relation between the productivity of a portion of the field as determined by a Kherson check, and the pro-

	130 to 140	140 to 150	150 to 160	160 to 170	170 to 180	180 to 190	190 to 200	200 to 210	210 to 220	220 to 230	230 to 240	240 to 250	250 to 260	260 to 270	270 to 280	Total
60 to 70								1								1
70 to 80		1		1					1							3
80 to 90				1			1		1	1	1		1			6
90 to 100					2	4		1	1	1		1				10
100 to 110		1	2		2	2	4	3	2	3	1					20
110 to 120			1		1	4	3	2	2	2	2	1				18
120 to 130			1		3	4	1	4	4	2	3					22
130 to 140	1					5	1	2	3	3	1	1	1		1	19
140 to 150					1	1	1	3	2	2	1					11
150 to 160								2	2							4
160 to 170					1			2	1	1						5
170 to 180										1						1
Total	1	2	4	2	10	20	11	20	19	16	9	3	2	0	1	120

FIGURE 7.—CORRELATION BETWEEN YIELDS OF KHERSON CHECK PLOTS AND YIELDS OF ADJACENT RED RUSTPROOF CHECK PLOTS, IN OATS VARIETY AND STRAIN TESTS 1921.

$r = +.162 \pm .060.$

ductivity of the same portion of the field as determined by an adjacent Red Rustproof check plot. This correlation is shown in figure 7. The coefficient of correlation is less than three times its probable error—the correlation has not even statistical significance! The relative productivity of different portions of the field, as indicated by the two check varieties, is shown in figure 8. If Kherson had been used as a check

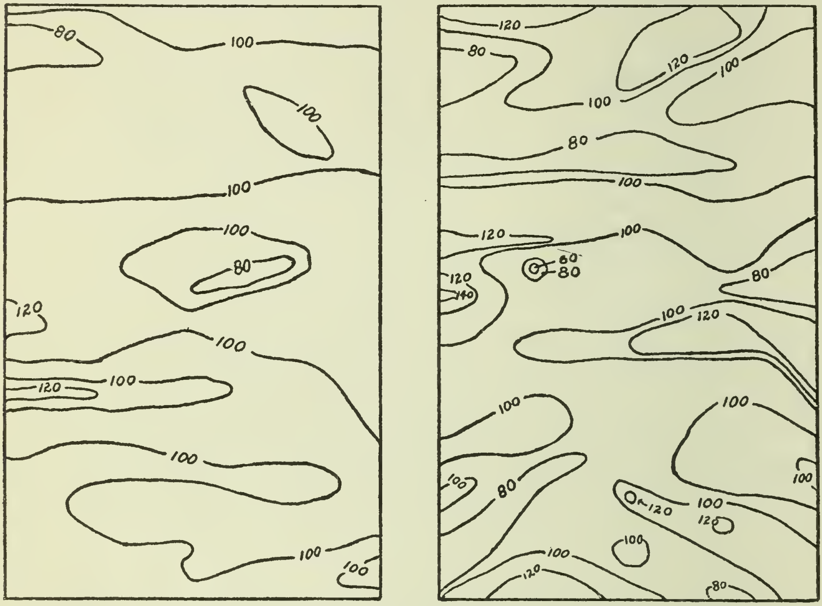

FIGURE 8.—RELATIVE VARIABILITY OF DIFFERENT PARTS OF AN EXPERIMENT FIELD, AS INDICATED BY THE YIELDS OF ADJACENT CHECK PLOTS OF KHERSON AND RED RUSTPROOF OATS. OATS VARIETY AND STRAIN TESTS 1921. In the diagram on the left, points of equal productivity, as indicated by the yields of the Kherson check plots, are connected by lines (as points of equal elevation are connected by lines on a contour map). In the diagram on the right, the same field is similarly mapped according to the yields of the Red Rustproof check plots. The numbers indicate the plot values of the points concerned.

variety for adjusting yields, the yields of certain plots would have been increased to compensate for the low productivity of the soil; if Red Rustproof had been used the yields of the same plots would have been decreased to compensate for the high productivity of the same soil. The fact is that certain parts of the field were actually more productive than the average for Kherson oats and less productive for Red Rustproof, as is indicated by the fact that each variety of check was considerably more effective in the adjustment of the yields of strains of the same variety than of strains of the other. But neither check was a very accurate measure of the productivity of the soil, even for its own variety, as indicated by the failure of adjustment to reduce variability consistently even when Kherson strains were ad-

justed according to the Kherson check and Red Rustproof strains according to the Red Rustproof check.

Value and Limitations of Adjusting Yields by Means of Check Plots.—The effect on plots variability of adjusting yields by means of check plots in all of the tests is shown in summary form in Table 40. The variability of the test plots was reduced by adjustment in three tests and was increased in the other five. It is noteworthy that the three tests in which plot variability was reduced by adjustment were characterized by high plot variability, as indicated by the standard deviation of check plots, while the tests in which adjustment was not

TABLE 40.—SUMMARY OF RELATIVE VARIABILITY OF ACTUAL AND ADJUSTED YIELDS OF INTERIOR ROWS IN ALL TESTS.

Test	Season	Number of varieties or strains	Number or replications	Average deviation Actual yields %	Adjusted yields %
Barley Variety	1919	27	3	15.35	12.91
Oats Variety	1919	24	3	10.23	8.27
Oats Strain	1919	15	4	5.96	6.80
Wheat Variety	1920	94	4	24.27	15.32
Wheat Variety	1921	94	3	10.45	11.52
Wheat Mixture	1921	30	4	9.84	13.81
Oats Variety	1921	32	4	10.86	11.43*
Oats Strain	1921	64	4	10.82	11.07*

*Adjustment by Kherson check.

effective were in general low in plot variability. In 1919 adjustment was quite effective in reducing variability in the oats variety test, while it increased variability in the oats strain test, which was conducted on the same field and similarly handled in every way. In fact, conditions were considered more favorable for the effectiveness of the practice in the strain test than in the variety test, for the check plots were closer together and 12 of the 15 strains tested were taxonomically identical with the check. But the standard deviation of check plots on the part of the field on which varieties were grown was almost twice as great as on the part of the field on which the strains were grown. Apparently the high variability of the plots in the variety test was caused in large part by differences in actual soil productivity which were largely counteracted by the adjustment of yields, while there was little variation in soil productivity in the strain test and such plot variability as occurred was largely due to other factors. In general therefore the adjustment of yields will probably be found more ef-

fective on fields highly variable in soil productivity than on more uniform fields, and for similar reasons the method will probably be found more effective in tests covering a rather large area than in tests covering a smaller area.

It is clear that the adjustment of yields by means of check plots entails several serious disadvantages, and may increase experimental error considerably. Not only is the yield of the check plot a far from perfect measure of soil productivity for the check variety, but the productivity of the same soil for other varieties may be decidedly different. The method is therefore more effective in tests of strains of the same variety as the check, than in tests of different varieties. When the yields of check plots are materially affected by factors not similarly affecting the neighboring test plots, adjustment of yields will increase experimental error. The check plots must therefore be effectively protected from competition, border effect, mechanical errors, and the like. Moreover, it is to be expected that the effectiveness of adjusting yields will vary with the season, since the relative influence of soil productivity on yield varies with the season. For example, in a season in which winter injury is exceptionally severe, actual soil fertility may have comparatively little to do with plot yields. Now, if the check variety is hardy, its yields may vary with the soil fertility, but when corresponding adjustments are made on the yields of tested varieties limited in yield by winter injury, a decrease in the variability of replicate plots is hardly to be expected. The same considerations apply of course to yields limited by many other factors.

But, although a multitude of objections may be made to the theoretical bases of the practice of adjusting yields in variety tests, and although in many cases it undoubtedly results in an increase rather than a decrease in experimental error, the practice offers promise of value and is worthy of further investigation. The effectiveness of the adjustment of yields in the wheat variety test of 1920, in which the variability of replicate test plots was reduced about 40 per cent, is a demonstration of the possibilities of the method. An increase in replication of plots involving the same increase in land and labor would probably have reduced plot variability only about 7 per cent. A thorough knowledge of the value and limitations of yield-adjustment by means of check plots might enable us to reduce variability, at least in some types of plot tests, much more effectively by this means than by replication. The saving in area required is of particular significance in preliminary tests if border rows must be used for the elimination of competition, since in this case the area required for a large number of replications is in many cases prohibitive.

CONCLUDING REMARKS

The best method for preliminary variety testing is one which will permit the accurate determination of the relative value of the varieties *under field conditions,* with the use of a small area of land for each variety. Some precision must be sacrificed to save land, and in so far as the errors involved are of such nature that their extent can be approximately determined, and conclusions drawn accordingly, this sacrifice of precision is permissible. In many cases it is advisable, for example, to reduce the number of replications and to increase the least difference in yield regarded significant to a sufficient degree to compensate for the decrease in precision.

But these considerations do not apply to systematic errors, which, since they affect the yields of replicate plots similarly, and consequently have little effect on plot variability, cannot be accurately measured. Typical systematic errors commonly involved in preliminary testing are (1) modification of growing conditions favoring some varieties more than others, such as hand planting or wide spacing between rows, and (2) competition between varieties of different type, resulting from the use of single-row plots. The relative value of varieties under such conditions may be vastly different from their relative value under typical field conditions. Even should measurable experimental error be reduced to the absolute minimum, such a variety test might give results entirely misleading. The error cannot be counteracted, as can non-systematic errors, by increasing the least difference considered significant, nor can the extent of error of this sort be measured or estimated by a study of the experimental results.

Systematic error must therefore be reduced by every practicable means. Growing conditions in the preliminary test should be made as similar to ordinary field conditions as possible. The effect of varietal competition must be reduced to the minimum. If this can be accomplished without increasing the size of plots, it is desirable to do so. On the other hand, if larger plots are necessary for the control of competition, larger plots should be used. If the area to be used for preliminary testing cannot be correspondingly increased, the number of replications can be reduced sufficiently to permit the use of the larger plots required on the area available. This will necessitate a decrease in the degree of precision of the test, and will reduce the rapidity of elimination of the less valuable varieties. But is it not better to eliminate the undesirable varieties slowly than to risk the elimination of desirable ones by a more rapid analysis?

The error from competition is greater when different varieties are compared than when different strains of the same variety are compared, and the extent of error is roughly in proportion to the degree of difference in type of the varieties tested. Competition was not found to be correlated closely enough with earliness of heading, earliness of maturity, height, or grain-straw ratio in these experiments to permit its control by grouping varieties in respect to these characters. The factor found most closely correlated with competitive value was yield, but the correlation even in this case was not close enough to permit of effective control by grouping varieties. Moreover, it would be impossible in practice to group varieties with regard to yield, since the relative yield of varieties varies so widely with the season. The variety expected to yield poorly is not ordinarily included in the variety test.

When different strains of the same variety are grown, the error from competition, in some cases at least, may be slight enough to justify the use of single-row plots. However, competition in such cases is not wholly absent, and may occasionally be quite marked. The importance of competition as a source of error in tests of pure line selections of the same variety merits detailed investigation. If it is found that the effects of competition between pure lines is slight it may be practicable to use single-row plots, or at any rate to use 3-row plots without discarding border rows. The latter method will reduce the error from competition materially, without necessitating the loss of any of the experimental area. When the same total area is used, however, single row plots are somewhat more reliable than 3-row plots, because more replications can be used. The best size of plot for ordinary variety testing, as indicated by this investigation, is probably the 3-row plot with border rows discarded. The length of the plot as harvested is assumed to be 16 feet, but the same considerations will apply for any other convenient length. The number of replications will vary with the heterogeneity of the field and the degree of precision required (and, to some extent, with the season and the variety).

Check plots have been used in preliminary variety tests mainly for the following purposes:

(1) For the adjustment of the yields of the test plots, and

(2) To provide a measure of plot variability for the field used, and thus to determine the degree of precision of the experimental results, or the number of replications which would be required for a given degree of precision.

In both cases the behavior of the check variety is the basis for conclusions regarding the tested varieties. This involves the assumption that different varieties of the same crop respond similarly

to varying conditions. In one case, reported in this paper, two standard varieties, used as duplicate checks, and grown side by side in 120 distributed sections of a field, showed no significant correlation in relative yield of adjoining plots, and differed so widely in plot variability that the number of replications necessary for a given degree of accuracy was more than twice as great for one check variety as for the other. Further investigation is necessary to determine how generally such cases may occur, but this single case indicates at least a possible source of extreme error in the use of check plots, either for adjustment of yield or for the determination of the probable error of the experimental results.

For this and various other reasons the adjustment of yields by means of check plots is at present of doubtful value as a general practice. In some cases, however, such adjustment accomplishes a great improvement in the precision of an experiment, with a relatively slight increase in expense. The practice is more promising for tests of strains or selections of the same variety than for tests of different types. A thorough study of the use of check plots in variety and strain testing may discover methods of overcoming the disadvantages, and thus make available an economical and effective method of increasing precision. Meanwhile, check plots should be used cautiously. Methods for adjusting yields and for determining the extent of plot variability without the use of check plots are available[17, 18], and check plots must demonstrate actual value if they are to continue in use in variety tests.

SUMMARY

1. In variety and strain tests of barley, oats, and wheat, in five-row blocks, the competing border rows of adjacent sorts gave relative yields often widely different from those of the interior rows of the same plots.

2. Such competitive effects were much more extreme between different varieties than between different commercial strains of the same variety.

3. A considerable error from competition affected tests in rows running north and south, as well as those in rows running east and west.

4. Although in general the higher yielding varieties were favored in competition, the reverse frequently occurred. In some cases a material advantage in yield in the interior rows was converted to a material disadvantage in yield in the border rows.

5. Competing quality was correlated fairly consistently with yield and with earliness of heading and maturity. No relation to grain-straw ratio was found in the one season in which this character was determined. A significant correlation between competition and height was found in the wheat variety test of 1921, but the relation of competition to height was not determined in the other tests.

6. In the oats tests competition was most closely related to earliness of heading and maturity, but was also related to yield. In the wheat, competition was related fairly closely to both yield and earliness. In the barley it was not significantly correlated with any of the characteristics studied, though the relation to yield was considerably closer than the relation to any of the other characteristics.

7. In the wheat and oats tests in which earliness and yield were correlated with competition, earliness and yield were correlated quite closely with one another.

8. Single-row plots, protected from competition by border rows discarded at harvesting, were somewhat more variable in yield than 3-row plots similarly protected, but the difference was not great enough to outweigh their advantage in size. The mean yield of five replicate protected single-row plots is therefore more reliable, under the conditions of these tests, than the mean yield of three replicate protected 3-row plots, which would occupy the same area and require considerably more labor in harvesting and threshing.

9. There was no consistent difference in variability between 3-row and 5-row plots.

10. Plot variability was increased with increase in the size of the experiment field. The number of replications required for a given degree of precision, as measured by the variability of plot yields, is therefore increased somewhat when border rows are added for the control of competition.

11. The variability of 120 distributed check plots of Kherson oats differed widely from that of 120 distributed plots of Red Rustproof oats, adjacent to them. If the variability of the check yields were considered a measure of the precision of the test, entirely different conclusions would be drawn on the basis of the yields of these two check varieties.

12. Adjustment of plot yields on the basis of the yields of check plots resulted in a decrease in plot variability in three tests and in an increase in five tests. In general the practice was effective on fields of high plot variability, and was ineffective on fields of low plot variability.

13. In the oats strain test in which both Kherson and Red Rustproof check plots were included, the Kherson check was more effective than the Red Rustproof check as a basis for adjusting the yields of the Kherson strains, while the Red Rustproof check was more effective as a basis for adjusting the yields of the Red Rustproof strains.

14. The correlation between the yields of adjacent Kherson and Red Rustproof check plots was not statistically significant. Adjustment of the yields of the Kherson check plots on the basis of the yields of the adjacent Red Rustproof plots, and of those of the Red Rustproof plots on the basis of the Kherson yields increased variability.

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Certain Responses of Apple Trees to Nitrogen Applications of Different Kinds and at Different Seasons

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Certain Responses of Apple Trees to Nitrogen Applications of Different Kinds and at Different Seasons.

H. D. Hooker, Jr.

A careful study of the literature dealing with fertilizer applications to fruit plants shows that those most commonly effective involve nitrogen. Other elements have been shown to be beneficial in many cases when applied to fruit plants, but not so consistently nor so strikingly. The relatively distinct effects that follow occasional applications of iron constitute an exception to the general statement, but only because the symptoms of iron deficiency are easily recognized and generally understood. For this reason, iron is seldom used as a fertilizer except where its requirement is clearly indicated by chlorosis. Were it possible to tell as readily when the other essential mineral elements become limiting factors of growth and production, the problem of fertilizer requirements would be relatively simple. In the absence of any symptoms more marked than a pale green color of the leaves or a small amount of new growth—conditions that may result from any one of a number of different causes—it is inevitable that many fertilizer applications should be without important effect, for they meet no requirement. On the whole, it is remarkable that nitrogen applications should be effective in increasing growth and crop producing power as generally as they do, a fact which indicates that nitrogen is more often the limiting factor of growth and yield in fruit trees than any of the essential mineral elements.

Nitrogenous fertilizers applied to fruit trees have quite generally increased the set of fruit, favored vegetative growth and increased yields. The experimental work by which these facts have been determined has been for the most part empirical. The orchard fertilizer problem has been attacked as a simple matter of generally increasing growth and productiveness. These are, to be sure, the objects of ultimate interest and of greatest importance, but the fertilizer problem is more complex. The response in terms of growth and yields is the culmination of many different activities—absorption, elaboration, utilization and storage—of correlative effects on other constituents, of distinct processes of growth, fruit bud differentiation, fruit setting and development, each of which is conditioned by different factors or sets of factors. For example:

Have the increased yields following the application of nitrogenous fertilizers resulted only from the better set of fruit and the increased size of the tree, or have nitrogen applications had a direct or indirect influence on fruit bud differentiation? Little attention has been given the effects of fertilizer applications made at times other than early spring. Is the season of application which is best for increasing the set of fruit likewise best for increasing fruit bud differentiation? The possible advantages to be derived from fertilizer applications evidently have not been exhausted.

The fertilizer problem should be studied as a problem in nutrition and the effects of nitrogen applications should be measured in terms of the chemical changes produced in various parts of the plant as well as in terms of growth and yield. Only by this method can principles of more or less general significance be determined. The following questions present themselves: Is the nitrogen content of a fruit tree increased by nitrogen applications? Does one form of nitrogenous fertilizer produce a greater immediate effect than another? Is the content of other constituents, particularly various forms of carbohydrate, altered? Are significant changes evident at the time of fruit bud differentiation and are different effects produced by applications at different seasons? In the hope of throwing light on some of these questions, the present investigation was begun in the spring of 1920.

MATERIALS AND METHODS

Through the kindness of Dr. J. C. Jones, President of the University of Missouri, two apple orchards at McBaine, Missouri, were placed at the disposal of the Department of Horticulture for experimental treatment and sampling. Each orchard contained York trees in good condition; those in the south orchard were 20 years old and bore in even years; those in the north orchard were 16 years old and bore in odd years. These trees were fertilized in a manner to be described presently and samples of spurs and of bark from the scaffold limbs, four to six inches in diameter, were collected at intervals during the year. The bark samples consisted of strips three-quarters of an inch wide and six to eight inches long, pointed at each end and including all tissue outside of the cambium. Not more than three strips were taken from a single tree at one sampling. The wounds were covered with white lead paint to prevent infection and undue water loss. The spur samples included 1919 and 1920 growth.

The other trees used for experimental purposes were at the Experiment Station Fruit Farm, Turner Station, Mo. Samples of spurs including 1919 and 1920 growth were collected from fertilized and check trees of Jonathan and Ben Davis varieties growing in bottom land and seven years old in 1920, when the samples were collected. Another fertilizer experiment was conducted on vigorous four-year-old Grimes trees at the Fruit Farm. Samples of spurs of various lengths were collected from mature Ben Davis trees growing in the University orchard at Columbia.

The chemical analyses were made after the manner detailed in Research Bulletin 40 of this Station. Determinations were made of dry weight, ash, potassium, phosphorus, nitrogen, reducing sugars, total sugars and starch.

In the spring of 1921 practically all blossoms in the orchards under study were killed by late frosts. Since it was impossible to determine the effects of all the fertilizer treatments as originally planned, some of the treatments were repeated in 1921. However, a large body of data had been collected which it seems advisable to publish, incomplete and fragmentary though it be, since it shows some significant and rather unexpected facts.

SPRING APPLICATIONS OF VARIOUS NITROGENOUS FERTILIZERS

This first experiment was made on York trees in their bearing year. Four plots of 15 trees each were selected; one was left as a check; another received 5 pounds of sodium nitrate per tree; another received 3 pounds of ammonium sulphate per tree and the other 5 pounds of a high grade of dried blood. By this treatment each fertilized tree received approximately the same amount of nitrogen. The applications were made March 19, 1920.

The greater crop produced by the fertilized plots was the most striking effect produced. The yields from the plots were as follows: 285 bushels from the check plot or 19.7 bushels per tree; 375 bushels from the blood plot or 25.0 bushels per tree; 381 bushels from the nitrate plot or 25.4 bushels per tree; 376 bushels from the ammonium sulphate plot or 25.1 bushels per tree. These figures show that the three types of fertilizers used produced practically the same effect in increasing yield. There were minor variations within the plots: one tree on the blood plot produced 40 bushels of apples; one tree on the ammonium sulphate plot bore so large a crop that the tree split to the ground under the weight of

fruit; the yields of the trees on the nitrate plot were more nearly uniform. No definite figures are available but the apples from the nitrate plot seemed to be slightly larger and somewhat less highly colored than those from the other plots.

The data in Table 1 show that neither the bearing nor the non-bearing spurs of the fertilized trees formed a larger number of leaves during the current season than did corresponding spurs on the unfertilized trees. The following spring there was no bloom on any of the plots. The chief effects of the fertilizer treatments observed were a deeper color of the foliage and an increased set of

TABLE 1.—AVERAGE NUMBER OF LEAVES PER SPUR ON FERTILIZED AND UNFERTILIZED YORK TREES.

	May 3	May 15	May 22
BEARING SPURS			
Check plot	7.0	9.1	9.25
Nitrate plot	4.8	7.2	7.34
Amm. sulphate plot	6.8	8.4	8.6
Blood plot	5.8	7.4	7.9
NON-BEARING SPURS			
Check plot	6.6	8.0	8.2
Nitrate plot	5.2	7.2	7.4
Amm. sulphate plot	6.0	7.4	7.6
Blood plot	5.7	7.1	7.4

fruit: 23.7 percent of the blossoming spurs on the check trees bore fruit and approximately 32 percent of the blossoming spurs on the fertilized trees, as determined by actual count.

Samples of spurs and of bark were collected from the trees on these plots at five dates; May 22, June 19, September 6, November 20, 1920, and April 2, 1921. The analytical determinations on these samples are given in Table 2. (See pages 8 and 9.)

The greater set of fruit on the fertilized trees is probably to be associated with the greater nitrogen content of their spurs on May 22, as suggested by Harvey and Murneek (Ore. Agr. Expt. Sta. Bul. 176). At this time the nitrogen content of the spurs is on the decline, as reference to Figure 10 in Research Bulletin 40 of this Station shows.

Except for this temporary increase in nitrogen content there is no very significant difference between the composition of the fertilized and unfertilized trees. The absence of such variations

is striking. There has been no marked starch accumulation in any of the spurs by June 19, immediately before the period of fruit bud differentiation. Moreover, on April 2 the following spring, the spurs of the fertilized trees contained very little more nitrogen than the check spurs, the difference found being well within the limits of experimental error. Similarly, though the nitrogen content of the bark from the nitrated trees is slightly greater than that of the check trees, the sulphate and blood trees have less. Consequently no consistent difference is evident.

The comparison between the chemical composition of spurs and bark from the same trees as afforded by the data presented is of considerable interest. In general, the variations in the chemical composition of the bark follow rather closely those in the spurs. The low starch content of the former in May and June is particularly striking as it indicates that the factors which prevent carbohydrate accumulation in the bearing spurs likewise affect the bark of the scaffold limbs. The high total sugar content of the bark during the winter and especially in April is apparently characteristic. The bark contains, during most of the year, about half the percentage of nitrogen that the spurs contain; its percentage phosphorus content is also, for the most part, much less but the percentage potassium content of these two portions of the tree is of the same order and during part of the year the bark contains an even higher percentage than the spurs. This is consistently true in the June and September analyses. The percentage ash content of bark is usually greater than that of the spurs though the difference is very nearly wiped out in the spring.

In this experiment the various types of nitrogenous fertilizers have produced essentially the same effects as shown both by the chemical analyses and the crop yields. This effect has consisted principally in an increased set. There has been no effect in increasing the number of leaves during the current season and very little effect, if any, on the rate of growth. There has been no effect on fruit bud differentiation nor any tendency in that direction, such as might be evidenced by an accumulation of starch in the spurs during the period of fruit bud differentiation. In fact, the greater carbohydrate utilization following the increased set of fruit would tend to decrease the chances for starch accumulation in the absence of an increased leaf area per spur.

Nitrogenous fertilizers should, therefore, be applied to biennially bearing apple trees in the spring of their crop year with ex-

treme caution, for such a practice is likely to lead to overproduction with its attendant evils.

TABLE 2.—ANALYSES OF SPURS AND BARK FROM FERTILIZED AND UNFERTILIZED YORK TREES IN THEIR BEARING YEAR.
(*Percentages of dry weight*)

	Dry weight	Reduc'g sugars	Total sugars	Starch	Ash	K	P	N
May 22, 1920								
BEARING SPURS								
Check	40.2	0.79	1.95	0.68	9.73	0.678	0.170	1.020
Nitrate	43.2	1.00	1.65	1.15	8.74	0.626	0.162	1.047
Sulphate	43.6	0.66	1.59	0.00	11.32	0.649	0.138	1.164
Blood	41.2	0.70	2.79	0.45	7.69	0.665	0.174	1.221
BARK								
Check	43.4	1.48	1.74	0.11	7.97	0.621	0.060	0.578
Nitrate	43.1	1.61	1.89	0.20	12.79	0.648	0.064	0.565
Sulphate	42.7	1.69	1.74	0.00	8.12	0.585	0.072	0.605
Blood	42.3	1.53	2.10	0.14	8.32	0.513	0.075	0.526
June 19, 1920								
BEARING SPURS								
Check	44.4	1.26	1.65	0.00	6.44	0.554	0.140	0.916
Nitrate	45.7	1.26	1.29	0.00	6.59	0.362	0.141	0.912
Sulphate	42.5	0.77	1.08	0.36	6.02	0.639	0.148	1.024
Blood	43.1	0.86	1.20	0.00	7.21	0.558	0.209	1.166
BARK								
Check	47.9	1.32	1.62	0.00	9.91	0.570	0.145	0.578
Nitrate	42.3	1.71	2.00	0.38	8.41	0.583	0.108	0.546
Sulphate	42.6	1.62	1.89	0.70	8.11	0.647	0.086	0.575
Blood	48.1	1.73	2.04	0.54	7.77	0.522	0.096	0.551
September 6, 1920								
BEARING SPURS								
Check	46.7	1.21	2.25	2.88	7.97	0.408	0.155	1.030
Nitrate	45.6	0.88	1.38	1.98	7.29	0.371	0.164	0.880
Sulphate	45.3	0.72	1.14	2.41	7.29	0.420	0.211	1.110
Blood	48.8	0.72	1.20	1.98	6.58	0.414	0.176	1.010
BARK								
Check	44.9	1.87	2.70	2.53	10.76	0.457	0.110	0.52
Nitrate	40.6	1.72	2.60	2.27	11.45	0.411	0.107	0.44
Sulphate	43.6	1.65	2.55	2.36	11.08	0.502	0.108	0.58
Blood	44.6	1.45	1.86	2.66	12.00	0.459	0.136	0.54
November 20, 1920								
SPURS								
Check	48.4	2.95	3.15	1.08	9.05	0.489	0.222	1.22
Nitrate	47.9	1.98	2.73	1.19	8.01	0.457	0.230	1.14
Sulphate	49.6	1.94	2.71	1.28	8.53	0.473	0.177	1.09
Blood	48.5	1.73	2.16	1.15	8.69	0.513	0.241	1.20

TABLE 2.—(Continued.)

	Dry weight	Reduc'g sugars	Total sugars	Starch	Ash	K	P	N
BARK								
Check	44.1	2.68	3.78	1.58	12.35	0.498	0.098	0.69
Nitrate	45.3	3.07	4.32	1.72	11.48	0.393	0.102	0.61
Sulphate	46.9	2.81	3.42	1.58	12.33	0.385	0.075	0.64
Blood	44.1	2.38	3.27	1.98	11.43	0.397	0.106	0.58
April 2, 1921								
SPURS								
Check	48.5	2.44	3.06	1.53	9.28	0.498	0.210	0.86
Nitrate	46.9	2.36	3.37	2.34	9.71	0.428	0.212	0.92
Sulphate	47.2	2.07	3.21	1.35	9.81	0.441	0.183	0.89
Blood	44.7	2.47	3.45	1.71	10.11	0.490	0.202	0.88
BARK								
Check	46.1	5.57	6.56	2.55	9.22	0.405	0.122	0.58
Nitrate	46.7	5.93	6.36	2.52	10.63	0.354	0.104	0.62
Sulphate	46.4	5.68	5.94	2.34	10.19	0.346	0.147	0.52
Blood	47.1	5.79	6.00	2.43	9.63	0.430	0.144	0.56

EFFECT OF SPRING APPLICATIONS OF NITRATE IN PROMOTING GROWTH

Spring applications of nitrogenous fertilizers not only have an effect on the setting of fruit, but, as is well known, they frequently increase the amount of growth. This effect is shown by an experiment on Ben Davis and Jonathan trees at the University Fruit Farm. Two trees of each variety were treated with three pounds of sodium nitrate in the spring of 1919 and again March 29, 1920. The effects of this treatment have been revealed in the greater size of the fertilized trees as compared with check trees of the same variety in the same rows. These trees blossomed for the first time in 1921 but the entire bloom was killed by spring frost.

Samples of spurs were collected from the fertilized trees and the checks at three dates, March 29, May 22 and June 19, 1920. The analyses of these spurs are given in Table 3.

The percentage nitrogen content of the spurs from the fertilized trees was less on March 29 than that of the check spurs, showing that the fertilizer applied the year before did not increase the nitrogen content of the spurs. In May, the fertilized spurs contained a higher percentage of nitrogen than the checks; but since their percentage nitrogen content continued to decline during the month following, while that of the checks increased, the fertilized

Table 3.—Analyses of Spurs on Fertilized and Unfertilized Jonathan and Ben Davis Trees.

(*Percentages of dry weight*)

	Dry weight	Reduc'g sugars	Total sugars	Starch	Ash	K	P	N
March 29, 1920								
Jonathan								
Nitrated	----	1.64	1.92	1.35	5.315	0.489	0.193	1.23
Check	----	1.71	1.77	1.08	6.480	0.558	0.220	1.35
Ben Davis								
Check	----	1.98	2.13	0.47	8.020	0.414	0.190	1.30
Nitrated	----	1.31	2.25	0.72	7.925	0.402	0.200	1.245
May 22, 1920								
Jonathan								
Check	42.9	1.04	1.88	1.01	4.76	0.722	0.131	0.857
Nitrated	40.9	1.22	2.34	0.00	4.70	0.423	0.127	0.927
Ben Davis								
Check	44.1	1.04	1.65	0.36	4.59	0.514	0.100	0.699
Nitrated	43.9	1.01	1.77	0.90	4.33	0.480	0.103	0.822
June 19, 1920								
Jonathan								
Check	45.1	1.08	2.67	2.16	4.64	0.457	0.157	0.897
Nitrated	47.1	0.70	1.86	1.60	4.51	0.455	0.144	0.820
Ben Davis								
Check	49.3	1.08	1.38	1.42	5.94	0.325	0.224	1.128
Nitrated	47.6	0.65	1.35	1.10	4.60	0.321	0.134	0.792

spurs again contained less than the checks on June 19. This slight difference in itself may not be particularly significant at this time, immediately preceding the period of fruit bud differentiation, but when considered in its relation with other conditions with which it is associated and for which it may possibly be responsible, it may assume great importance. At this time the starch content in the spurs of the fertilized trees was distinctly less than in the check spurs. This indicates clearly that the conditions for fruit bud differentiation were not improved and in fact were made less favorable by the spring application of nitrate of soda. The smaller accumulation of starch in the spurs of fertilized trees immediately before the period of fruit bud differentiation is probably related to, if not actually caused by, the more vigorous growth of the fertilized trees.

It is evident that the minimum nitrogen content occurred much sooner in the spurs of the check trees than in those of the

fertilized trees and this minimum is related to the time of growth cessation, for an accumulation of nitrogen as shown by an increased percentage does not usually occur in spurs until growth has ceased. The figures in Table 3 show that the potasssium and total ash content of the fertilized spurs is consistently less than in the check spurs and for the most part this is true also of the phosphorus content. These conditions may be interpreted as further consequences of the more vigorous growth of the fertilized trees for it is a general rule that the greater the length of the spur growth, the lower is its ash content at the close of the growing season. This is shown by the data in Table 4 which are analyses of Ben Davis spurs collected May 21 and July 2, 1920. The samples were collected according to spur lengths as shown in this table. It will be seen that the ash, phosphorus and nitrogen content is less, the longer the spur growth of the current season.

TABLE 4.—ANALYSES OF BEN DAVIS SPURS ACCORDING TO LENGTH
(1919 and 1920 wood included)
(*Percentages of dry weight*)

Spur length in centimeters	Dry weight	Ash	K	P	N
May 21, 1920					
0.5- 1.0	48.8	6.15	0.597	0.179	0.891
1.1- 1.5	45.6	5.28	0.568	0.177	0.876
1.6- 3.0	41.2	4.91	0.536	0.137	0.705
3.1-10.0	36.9	4.49	0.572	0.133	0.700
July 2, 1920					
0.5- 1.0	48.4	6.44	0.513	0.142	0.754
1.1- 1.5	47.3	5.53	0.531	0.134	0.754
1.6- 3.0	46.9	5.04	0.527	0.138	0.726
3.1-10.0	46.8	4.18	0.475	0.118	0.684

THE EFFECT OF SPRING APPLICATIONS ON IMMATURE TREES

On March 29, 1920, two plots of young Grimes apples were fertilized, one with 2 pounds of nitrate of soda and one with 2 pounds of dried blood to the tree. Each plot contained 10 trees and a similar block of 10 trees was left as a check. About 50 short, spur-like growths and 13 leaders on the trees of each plot were labeled. Growth measurements were made on these spur-like growths and on the four shoots arising from the terminal portion

of each leader. The effects of the fertilizer treatments on the growth of these trees is shown in Table 5. It is evident that the nitrate of soda had a greater effect on the shoot growth than did the dried blood. Practically no difference is evident between the rates of growth from the short spur-like branches.

Chemical analyses of these two types of growth are shown in Table 6. The absence of any marked differences between the various plots is quite striking. Differences do appear, however, in the chemical composition of the terminal growth as compared with that of the shorter spur-like branches. In the former there is no complete disappearance of starch in June and the nitrogen content

TABLE 5.—AVERAGE LENGTHS IN CENTIMETERS OF GROWTHS FROM LEADERS AND SPUR-LIKE BRANCHES ON FOUR-YEAR-OLD GRIMES.

	May 5	May 14	May 21	May 31	June 14	July 9
LEADER GROWTH						
Check	2.24	8.5	12.2	19.5	28.0	35.8
Nitrate	2.23	9.8	14.7	22.5	31.9	42.6
Blood	2.18	8.7	12.5	19.0	27.5	34.6
TWIG GROWTH						
Check	2.4	7.2	9.4	13.0	15.3	16.1
Nitrate	2.2	7.5	10.6	13.9	15.6	16.0
Blood	2.7	9.3	10.4	13.3	15.8	16.8
AVERAGE NUMBER OF LEAVES ON TWIG GROWTH						
Check	6.0	9.3	10.0	12.0	13.9	14.2
Nitrate	7.2	8.9	10.1	11.8	12.9	13.1
Blood	7.5	9.8	10.8	12.3	13.5	14.6

rises to a high maximum in May, much as in bearing spurs on mature trees.

The only apparent difference associated with the greater terminal shoot growth of the nitrated trees is shown in a higher percentage of starch and total sugar and a lower percentage of ash, potassium and phosphorus in June. In September these shoots have the highest percentage of ash and potassium and the lowest of phosphorus and nitrogen.

The data presented indicate a differential effect between nitrate of soda and dried blood, which may be associated with the more quickly available character of the former. Different parts of a tree evidently may react in different ways to the same fertilizer treatment. A comparison of the responses of these four-year-old trees with those of the Ben Davis, Jonathan and York trees indi-

TABLE 6.—ANALYSES OF GROWTHS FROM LEADERS AND SPUR-LIKE BRANCHES ON FOUR-YEAR-OLD GRIMES.

(Percentages of dry weight)

	Dry weight	Reduc'g sugars	Total sugars	Starch	Ash	K	P	N
May 21, 1920								
LEADER GROWTH								
Check	25.8	0.97	1.17	2.09	4.49	1.435	0.234	1.625
Nitrate	25.1	0.77	1.35	2.05	4.61	0.669	0.236	1.625
Blood	25.2	1.01	1.26	2.70	4.56	1.011	0.216	1.615
SPUR-LIKE GROWTH								
Check	31.0	0.86	1.44	1.96	4.63	0.599	0.204	1.299
Nitrate	33.6	0.90	1.08	1.51	4.17	0.706	0.152	1.045
Blood	33.0	1.08	1.08	1.58	4.26	0.579	0.181	1.150
June 19, 1920								
LEADER GROWTH								
Check	38.7	0.88	1.62	2.18	3.64	0.791	0.147	0.845
Nitrate	38.5	1.10	1.95	2.75	3.08	0.642	0.137	0.952
Blood	38.7	1.28	1.62	2.12	3.54	0.697	0.142	1.063
SPUR-LIKE GROWTH								
Check	46.8	0.95	1.41	0.02	4.20	0.578	0.163	0.739
Nitrate	44.0	0.90	1.47	0.00	4.19	0.689	0.183	0.829
Blood	46.8	1.13	1.72	0.00	4.00	0.299	0.145	0.675
September 4, 1920								
LEADER GROWTH								
Check	39.0	0.54	0.90	1.40	3.08	0.319	0.177	0.76
Nitrate	39.6	0.67	1.05	1.44	3.55	0.685	0.150	0.64
Blood	39.4	0.29	0.60	1.73	3.23	0.554	0.153	0.66
SPUR-LIKE GROWTH								
Check	53.0	0.50	0.75	2.30	5.31	0.433	0.189	0.75
Nitrate	53.0	0.81	1.23	1.89	4.98	0.411	0.197	0.73
Blood	54.3	0.68	1.23	2.05	6.01	0.406	0.196	0.81

cates that the age of the tree may be an important factor, although it is quite possible that the observed differences may have been due to the conditions under which the various trees were growing.

THE EFFECT OF APPLICATIONS AT DIFFERENT SEASONS

Fertilizer applications were made on 16-year-old York trees in their off year. One plot of 15 trees was fertilized March 29 with dried blood and another on June 20. Both times 5 pounds of fertilizer were applied to each tree. On September 20 another plot of 15 trees was given 5 pounds of sodium nitrate to the tree. Be-

cause of the severe spring frosts of 1921, the effects on these trees could not be measured except in terms of the chemical changes observed in the bark and spurs. These are given in Table 7.

The data afford a comparison with Table 1 of the chemical composition of bark on bearing and non-bearing trees. In general the seasonal changes in the chemical composition of the bark on the scaffold limbs of these alternate bearing trees follow those of the spurs. In June there is already an accumulation of carbohydrate in the form of starch. In May the nitrogen content is somewhat less in the non-bearing trees. During the winter the sugar content of the bark is exceptionally high, much higher in the non-bearing than in the bearing trees. From September through March the potassium content of the non-bearing trees is distinctly higher and the phosphorus and nitrogen content likewise, though to a lesser extent.

The differential effects from applying these fertilizers at various seasons is most evident in the nitrogen content of the spurs. On March 30, 1921, the nitrogen content of the spurs varies with the lateness of application the previous season. The check spurs have the least, the spring fertilized trees next, the summer fertilized trees more and the fall fertilized trees most of all. Moreover these differences in nitrogen content are by no means insignificant. It is unfortunate that weather conditions made it impossible to follow the later effects associated with these differences in the nitrogen content of the spurs. It is impossible to say what advantage might accrue from increasing the nitrogen content of spurs in the spring of their bearing year but it is clear that late summer or early fall applications of nitrogenous fertilizers are much more effective in this respect than spring applications.

The effect of spring application of blood on these non-bearing trees is essentially the same as that observed on the Ben Davis and Jonathan trees. The accumulation of starch in the spurs toward the end of June at the critical time of fruit bud differentiation is reduced by the spring application of dried blood just as it was by the nitrate of soda in the Ben Davis and Jonathan spurs. Moreover, the residual effect of the spring fertilizer, as shown by the analyses of March 30, 1921, is practically nil, as in the case of the bearing York trees.

The most marked effect on the nitrogen content of the bark was produced by the summer application of dried blood. In September and December the nitrogen content of the bark on the sum-

TABLE 7. ANALYSES OF SPURS AND BARK FROM FERTILIZED AND UNFERTILIZED YORK TREES IN THEIR OFF YEAR.
(*Percentages of dry weight*)

	Dry weight	Reduc'g sugars	Total sugars	Starch	Ash	K	P	N
May 27, 1920								
SPURS								
Check	45.6	1.17	1.50	0.92	8.98	0.593	0.123	0.773
Blood	44.3	1.30	1.56	1.13	8.99	0.659	0.125	0.800
BARK								
Check	42.1	1.38	1.77	0.72	11.62	0.601	0.083	0.555
Blood	42.5	1.51	1.59	0.72	11.80	0.503	0.064	0.576
June 24, 1920								
SPURS								
Check	49.4	0.92	1.38	2.88	6.665	0.516	0.227	0.960
Blood	48.1	0.83	1.56	1.87	5.818	0.615	0.142	0.706
BARK								
Check	43.5	0.94	----	2.30	7.845	0.558	0.084	0.550
Blood	43.8	1.10	1.89	2.00	7.640	0.540	0.144	0.721
September 20, 1920								
SPURS								
Check	53.9	0.79	1.24	2.75	10.38	0.445	0.202	0.95
Spring blood	55.6	0.61	0.90	2.48	8.66	0.394	0.182	0.90
Summer blood	56.4	0.61	1.30	1.69	11.25	0.461	0.217	1.04
BARK								
Check	48.1	0.90	1.08	3.19	8.87	0.579	0.113	0.58
Spring blood	44.8	0.70	1.02	2.23	9.56	0.603	0.079	0.52
Summer blood	45.6	0.79	0.99	2.25	9.05	0.658	0.117	0.66
December 3, 1920								
SPURS								
Check	44.7	2.78	2.79	1.51	8.85	0.539	0.233	1.09
Spring blood	46.1	2.90	3.00	2.09	10.17	0.437	0.214	1.17
Summer blood	46.0	3.05	3.30	2.23	9.96	0.461	0.240	1.19
Fall nitrate	46.8	2.32	2.70	2.18	8.82	0.450	0.253	1.33
BARK								
Check	53.8	4.22	5.70	1.91	10.28	0.587	0.110	0.72
Spring blood	53.4	5.17	5.58	1.13	10.14	0.626	0.106	0.72
Summer blood	54.6	4.57	4.98	1.93	9.84	0.659	0.123	0.91
Fall nitrate	54.4	5.02	5.22	1.22	9.82	0.595	0.159	0.77
March 30, 1921								
SPURS								
Check	48.1	1.46	1.83	0.81	11.90	0.531	0.181	0.85
Spring blood	46.3	1.40	1.74	0.77	10.24	0.525	0.223	0.92
Summer blood	45.2	1.26	1.59	0.45	10.72	0.539	0.242	1.01
Fall nitrate	46.2	1.19	1.29	0.88	9.89	0.438	0.194	1.17
BARK								
Check	47.3	4.86	5.73	1.40	8.82	0.624	0.171	0.65
Spring blood	47.2	4.48	5.16	2.79	8.78	0.666	0.139	0.68
Summer blood	48.3	4.73	5.13	2.14	8.73	0.654	0.137	0.65
Fall nitrate	47.1	4.00	4.77	3.58	8.74	0.656	0.155	0.70

mer-fertilized trees was distinctly higher than that on the others but this difference had completely disappeared by the end of March, 1921.

It is interesting that the nitrogen content of the bark on the spring-fertilized trees was apparently increased at the end of June while the nitrogen content of the spurs was much less at that time.

DISCUSSION

The analyses reported in this paper confirm and extend those published in Research Bulletin 40 of this Station. Certain seasonal chemical changes characteristic of bearing and of non-bearing apple spurs and certain changes in bark and spurs characteristic of apple trees in their on and off years—the years of fruit production and those of fruit bud differentiation respectively—may be considered established. Particular physiological processes are apparently associated with definite chemical conditions existing in the spur at critical times. Fruit bud differentiation, for example, is associated with starch accumulation in the spur late in June and, since no exception has been found to this rule, it seems safe to conclude that the conditions which bring starch accumulation about are among the factors that determine fruit bud differentiation, though the existence of other factors which are at times decisive is unquestionable. In order to account for the known facts relative to the initiation of the fruitful state it seems necessary to postulate two conditions for fruit bud differentiation: (1) that carbohydrate (or starch) accumulation be possible and (2) that no other factor such as nitrate, water or heat supply be limiting to the extent that vegetative development is stopped or seriously retarded. These points are discussed in Research Bulletin 47 of this Station, where it is also shown that the conditions determining starch accumulation and fruit bud differentiation are not always confined to the spurs. In a similar way other processes are found to be associated with particular features of the seasonal chemical picture. Thus recent investigators have pointed out that fruit setting seems to be related to the nitrogen content of the spur in May and vegetative extension is evidently related to a number of factors.

The data presented in this paper also show some of the effects of applying nitrogenous fertilizers of various kinds and at different seasons with special reference to the chemical composition of bark and spurs. These effects depend primarily on the condition of the

tree and might well be influenced also by climatic conditions. All the work reported here deals with apple trees in fairly good condition. The type of nitrogenous fertilizer is evidently important under certain circumstances; under others it is not. Various physiological processes are affected more or less independently and there are indications that the season when the applications are made is an important factor in determining how these processes are affected.

An intelligent use of fertilizers evidently must be based on a recognition of the particular process which it is advisable to control and on a knowledge of the effects that applications of various kinds and at different seasons will have on this process. In the past when nitrogenous fertilizers have appeared necessary, a suitable amount has been determined on and has been applied in the cheapest or most readily available form in early spring. This precedure is inadequate as a panacea and the facts presented show that it may produce effects directly opposite to those desired. Trees that bear light crops regularly every year and in whose annual yield a material increase is desired present a case for treatment as different from that of trees which bear heavy crops biennially and which it is desired to make regular producers as this in turn is different from the case of trees which bloom profusely every spring but set little or no crop because nitrogen is a limiting factor. In one case it may be a question of stimulating general vegetative growth and vigor; in another of affecting fruit bud differentiation; in another of increasing the set of fruit. The same treatment will not bring about the desired result in all cases. Each is a problem for separate consideration and each involves phases which should be studied under a wide variety of conditions. There are, of course, limits to the effectiveness of nitrogenous fertilizers, but even where a requirement for nitrogen can be established, the best method of application in one instance may be entirely different from the best for some other case. The effect of early spring applications of quickly available nitrogenous fertilizers in aiding the set of fruit has been established and evidence is given that fruit bud differentiation and vegetative development also can be influenced in specific directions according to the time and type of application.

CONCLUSION

The chief effects of spring applications of nitrogenous fertilizers to healthy apple trees are, on bearing trees, an increased set of fruit associated with a greater nitrogen content in the spurs during the period of fruit setting and in non-bearing trees an increased rate of growth. Different types of quickly available nitrogenous fertilizers produce essentially the same effects though nitrate of soda stimulated leader growth on very young trees more than dried blood. Spring applications of nitrogenous fertilizers do not favor starch accumulation at the period of fruit bud differentiation and consequently they could not be expected to favor this process. No effects of spring applications are evident in the percentage nitrogen content the spring following the treatment, though larger absolute amounts would be present in the larger trees.

The later in the season nitrogenous fertilizers are applied, the greater is the nitrogen content of the spurs the following spring immediately before growth begins.

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The Influence of the Plane of Nutrition On the Maintenance Requirement of Cattle

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The Influence of the Plane of Nutrition On the Maintenance Requirement of Cattle

A. G. Hogan, W. D. Salmon, H. D. Fox

In 1914 an investigation* was begun at the Missouri Agricultural Experiment Station to study effects of underfeeding. Calves of beef breeding were secured, divided into three groups, and each group was placed on a different plane of nutrition. Group I was fed to grow rapidly, but not to become fat. Group II was placed on a lower nutritional plane, and was fed to gain about one-half pound per day. Group III was placed on a still lower plane and was fed to gain about one-third of a pound per day.

There were large differences in the food intake of the three groups, and after a considerable amount of data had been obtained it was decided to make a study of the maintenance requirement of these steers.

REVIEW OF LITERATURE

There has accumulated a considerable mass of literature concerning the maintenance requirement, in terms of energy, of animals as well as of man. Much of this material has no direct bearing on the problem discussed in this paper, but a short historical statement may be useful.

Waters[1] pointed out in 1908 that if the ration of an animal were suddenly reduced to a point a little less than sufficient to maintain its weight, there would be a process of readjustment. After a time a stationary live weight would be obtained if the reduction were not too severe, and following that there might be an increase in weight.

More recent data from the Missouri Experiment Station[2] show a lower maintenance requirement for animals on a low plane of

*This investigation was initiated by F. B. Mumford, Dean of the College of Agriculture, and P. F. Trowbridge, formerly chairman of the department of agricultural chemistry. Since September, 1918, E. A. Trowbridge, chairman of the department of animal husbandry, has had general supervision of the project. This article was prepared by A. G. Hogan, who has been in immediate charge since September, 1920. Mr. Salmon supervised the preliminary calculations, and calculated the data for the summer periods. Mr. Fox made the calculations for the winter periods. A large number of workers have contributed to the success of the investigation, but it does not seem practicable to mention them all individually. A short article embodying the essential points of the investigation was published in the Journal of Agricultural Research, Vol. XXII, p. 115.

[1]Refers to Bibliography, page 21.

nutrition. Three steers were full-fed until eleven months old, then subjected to a maintenance trial. In order of economy in maintenance requirement they ranked as follows: Steer 598 first, Steer 596 second, Steer 590 third. Following this No. 596 was full-fed, No. 598 was given one-half productive feed, and No. 590 one-fourth productive feed. The steers were again subjected to a maintenance trial in which they ranked as follows No. 590 first, No. 598 second, No. 596 third. Evidently the maintenance requirement closely paralleled the plane of nutrition.

Armsby[3a] cites the observations of Zuntz and Hagemann showing that a surplus of feed stimulated muscular activity and restlessness of the horse to such an extent that a ration more than sufficient for maintenance of this animal when standing quietly in its stall, would not cause an increase in weight under ordinary conditions. Experiments with cattle[4] indicate a similar stimulating effect upon their muscular movements. Armsby, therefore, concludes that at least a part of the lower maintenance cost may come from "voluntary restriction of motion on the part of the animals on a low nutritive plane."

An experiment by Armsby and Fries[5] showed that the maintenance requirement of a two-year-old steer was increased 36 percent by a three-month fattening period in which the live weight was increased by about 300 pounds. The computed basal metabolism per 1000 pounds live weight per day showed the following variations in maintenance requirement:

	In proportion to weight	In proportion to 2-3 power of live weight
Unfattened	4,919 cal.	5,125 cal.
Fattened	5,275 cal.	5,943 cal.

"The basal katabolism increased faster than the body weight or the body surface as estimated by the Meeh formula. Apparently the accumulation of fat tended in some way to stimulate the general metabolism." Both Kellner and Evvard have reported data, cited by Armsby[3b] showing that fat steers have a higher maintenance requirement than those in medium condition.

The extensive researches of F. G. Benedict and co-workers[6] in the field of human physiology are of especial significance. They have demonstrated that the basal metabolism of their subjects was markedly lower on a restricted diet than on a normal diet. In other words the maintenance requirement was lowered. In most

cases we have mentioned it is impossible to decide to what extent decreased muscular activity accounts for the lower maintenance requirement when animals are on a low nutritive plane.

EXPERIMENTAL

The conditions of this investigation are unique in one respect, the animals were started on the project at weights varying from 154 to 238 pounds and thereafter were kept constantly on the same plane of nutrition. Since the animals were under observation for from four to seven years, any marked or permanent adjustment to nutritional conditions should become apparent.

The ideal method of conducting an investigation of the maintenance requirement of cattle would provide for a respiration calorimeter. Since that was impossible the alternative was to calculate the energy value of the food consumed, and correct this for the estimated value of the gains (or losses) in body weight. The net energy of the feed consumed was calculated in accordance with procedures developed by Armsby. The energy values of the changes in body weight were calculated from the composition of steers that had been analyzed by the department of agricultural chemistry at this station.

Experimental Animals.—Three of the steers now under observation were started on the investigation in 1914, and seven others were added in 1917. Some of the more significant early records are condensed in the following table.

TABLE 1.—GROUPS, DATES OF BIRTH, AND BREEDS OF ANIMALS.

Animal	Group	Date of birth		Date put on Exp.		Weight when put on Exp.	Breed
528	I	May 8,	1914	June 11,	1914	157	Hereford-high-grade
577	I	March,	1914	Aug. 5,	1917	227	Shorthorn-grade
571	I	March,	1917	Aug. 5,	1917	158	Hereford-grade
579	II	May 2,	1914	May 30,	1914	154	Shorthorn-grade
573	II	April,	1917	Aug. 5,	1917	203	Hereford-grade
578	II	April,	1917	Aug. 5,	1917	238	Hereford-grade
585	III	April 26,	1914	May 22,	1914	123	Hereford-high-grade
572	III	April,	1917	Aug. 5,	1917	196	Hereford-grade
574	III	April,	1917	Aug. 5,	1917	237	Hereford-grade
575	III	April,	1917	Aug. 5,	1917	204	Hereford-grade

Quarters.—The steers had access to a shed open to the south. Adjoining this shed were dry lots sloping to the south, and having shade protection.

Rations.—The concentrate consisted of the following mixture: Corn chop, 60 percent; wheat bran, 30 percent; linseed meal, 10 percent. The roughage fed from the beginning of the experiment until July 20, 1917, was timothy. For the next ten days a mixture of 5 parts timothy, 3 parts alfalfa and 2 parts oat straw was fed. Following this the roughage consisted of a mixture of 60 percent alfalfa and 40 percent oat straw. The animals were fed twice daily and had access to water at all times. Salt was accessible at feeding time.

Weights.—The steers were weighed each morning, after feeding, but before watering. The weight given for the beginning of a period is the average of the ten preceding days. The weight given at the end is an average of the last ten days of the period.

Periods.—The calculations are made for periods of 180 days, with the exception of the first period for each of the three older steers, which were as follows: No. 528, 130 days; No. 579, 142 days; No. 585, 150 days. In order that one period each year might be free from the disturbing effects of cold weather, the year was divided into a "summer" and "winter" period. The summer periods began in April or May, and ended in October. The winter periods began in October or November and ended in April or May.

Energy Intake.—Our calculations of the energy values of the feed consumed are based on two methods described by Armsby[4]. In one case the dry matter, in the other the digestible organic nutrients consumed, was used to calculate the net energy intake of the steers.

The method of calculation based on dry matter consumed is as follows. For the concentrates the value 83.82 therms per 100 pounds dry matter was used. This is the factor given for Armsby's grain mixture No. 2*, which approximates the grain mixture used in this experiment. For timothy hay the value 48.63 therms per 100 pounds dry matter was used. The factor for the roughage mixture used in the latter part of the experiment was calculated from the Armsby values, for alfalfa 34.10 therms, and for oat straw

*Armsby's grain mixture No. 2—60 percent corn meal; 30 percent crushed oats; 10 percent O. P. linseed meal.

Our grain mixture—60 percent corn meal; 30 percent wheat bran; 10 percent O. P. linseed meal.

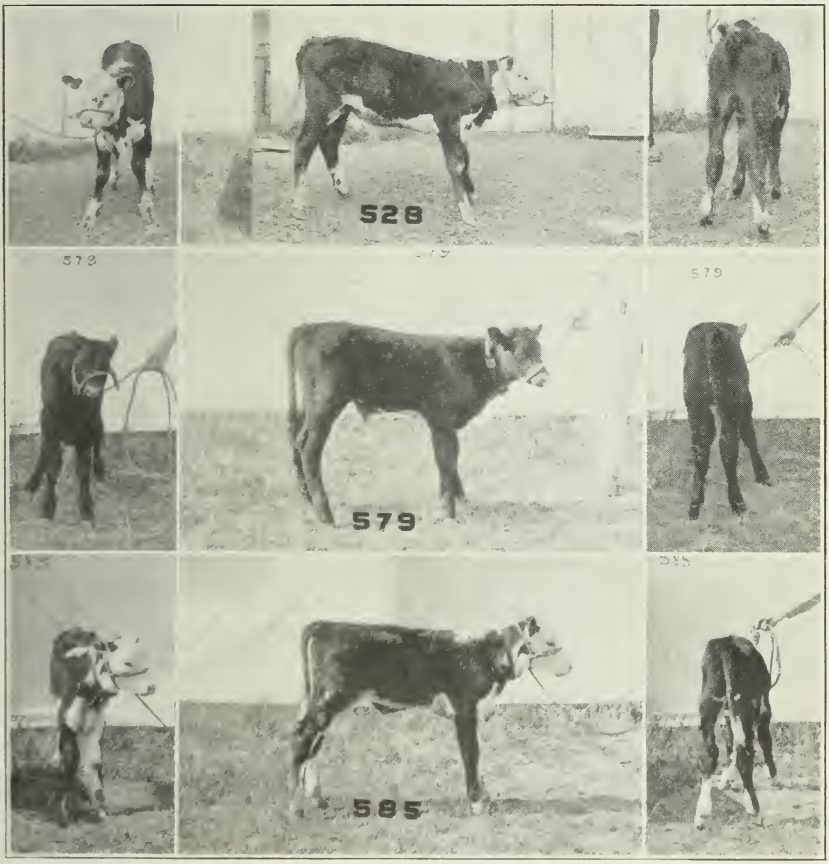

Plate I.—Taken at the beginning of the investigation.

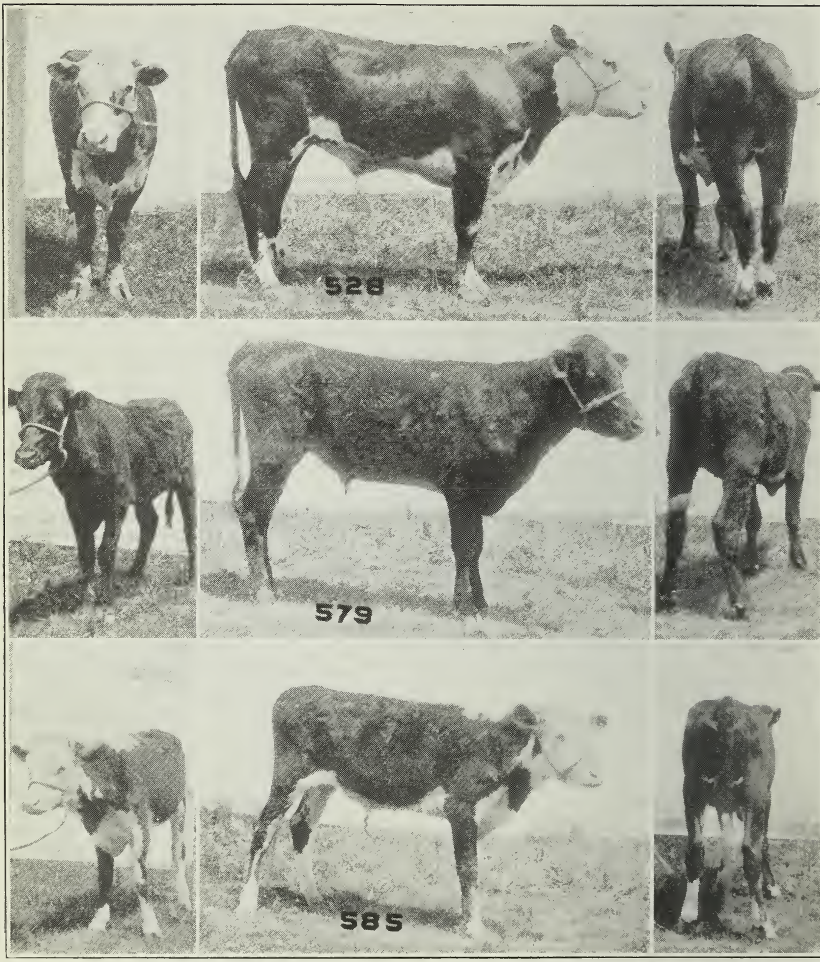

Plate II.—Taken after being fed three years on their respective nutritional planes.

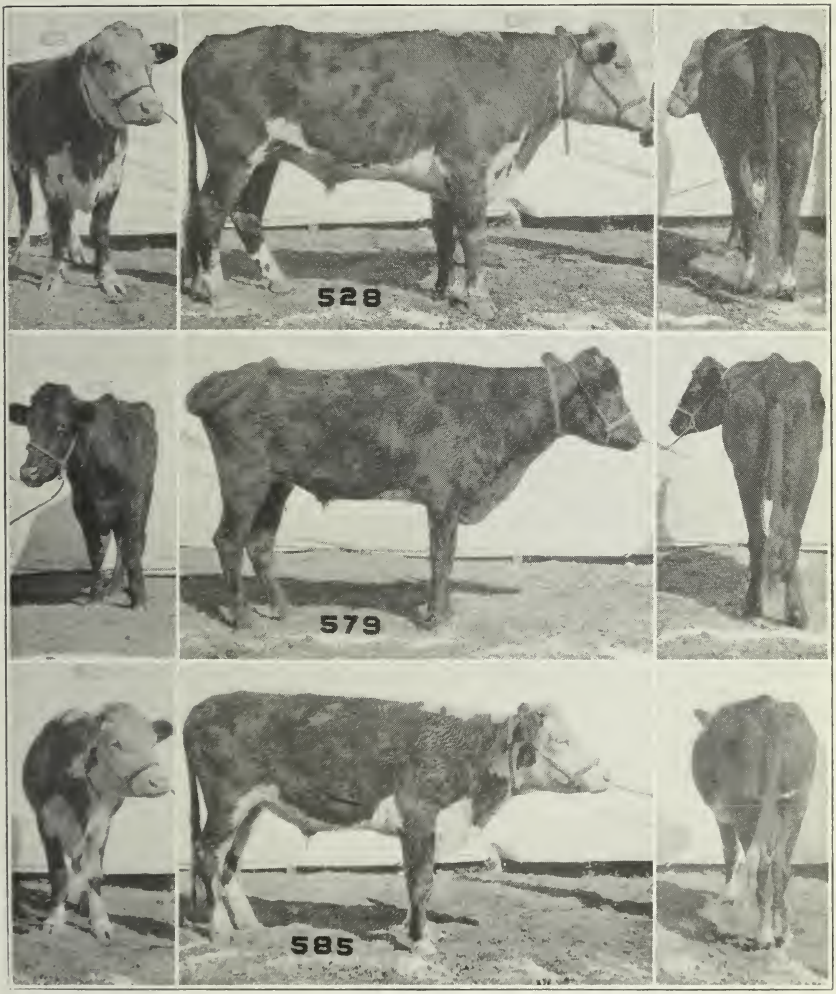

Plate III.—Taken after being fed six years on their respective nutritional planes.

26.03 therms per 100 pounds dry matter. A mixture of 60 parts alfalfa and 40 parts oat straw would have a value of 30.87 therms per 100 pounds dry matter.

The values used are summarized below in tabular form.

Table 2.—Energy Values per 100 Pounds Dry Matter.

	Net energy values in therms
Alfalfa hay	34.10
Oat straw	26.00
Mixture, 60 percent alfalfa, 40 percent oat straw	30.87
Timothy hay	48.63
Grain	83.82

The calculations of the energy value of the milk are also based on factors published by Armsby[3c]. These are 29.01 therms per 100 pounds whole milk (4.4 percent) and 14.31 therms per 100 pounds skim milk (0.2 percent). From these values factors were computed for the different grades of milk used. The values used are given in Table 3.

Table 3.—Net Energy Value of Milk Used.

Percent fat in milk	Therms net energy per hundred pounds
4.40 (whole milk)	29.010
3.20	24.776
2.70	23.130
1.85	20.086
1.20	17.838
0.20 (skim milk)	14.310

The net energy intake, based on digestible organic nutrients consumed, was calculated by the procedure outlined below.

The Armsby factor for the metabolizable energy of digestible organic matter from roughage is 1.588 therms per pound. For grains and similar feeds the factor is 1.769 therms per pound.

Armsby[3d] has also determined the "average energy expenditure" by cattle per 100 pounds of dry matter eaten. This is given in Table 4.

TABLE 4.—ENERGY EXPENDED BY CATTLE PER 100 LBS. DRY MATTER CONSUMED.

Roughage	Energy expenditure in therms
Timothy hay	35.47
Alfalfa hay	53.03
Oat straw	46.00
Concentrate	
Grain mixture No. 2	51.76

The coefficients of digestibility used in these calculations were derived from digestion trials conducted under similar conditions at this Station.[7] These indicated that the digestibility of the ration varied with the relative amounts of hay and grain fed. The factors used are given below.

TABLE 5.—DIGESTION FACTORS FOR ORGANIC MATTER.

Ratio of grain to hay	1:1	2:3	1:2	1:3, 4 or 5	1:6 or 7	1:8, 9 or 10	Hay only
Factor	.6956	.6695	.6434	.6340	.6229	.6030	.5832

Inasmuch as the thermal value of a pound of organic matter from grain differs from that of a similar weight of organic matter from roughage, the Armsby factors previously quoted in this paper could not be directly applied to the values obtained with the above digestion coefficients. Those factors would not provide for the widely varying proportions of grain and hay. The following method therefore was used in computing the energy intake on the basis of digestible organic matter consumed. By use of the factors in Table 5 the weight in pounds of digestible organic matter in the mixed ration was determined for each period. This was multiplied by 1.588, the Armsby factor for metabolizable energy in a pound of digestible organic matter from hay. The thermal value of digstible organic matter from grain is 1.769 however, or 0.181 therms more. Therefore each pound of digestible organic matter derived from grain was multiplied by 0.181, and the product added to the result obtained by multiplying the total digestible organic matter by 1.588. This gave the total metabolizable energy in both the hay and grain. The digestibility of the organic matter of the

grain was estimated by difference. This ranged closely around 80 percent. The factors for energy expenditure are given in Table 4.

It seemed impracticable to calculate the net energy of the milk consumed on the basis of digestible organic matter, so the calculation based on dry matter was used for milk. Since the amount was small, however, the method of calculation would have little effect on the final results.

Changes in Body Weight.—In order to obtain data concerning the maintenance requirement of these steers, it is necessary to calculate the energy gained or lost through changes in body weight. Our calculations are based on analyses previously made by the department of agricultural chemistry*, University of Missouri. Control animals were selected from those on which analyses were available, on the basis of similar weights and measurements, and when possible of similar ages, daily gains and daily consumption of dry matter. In some cases suitable check animals were not available, and the composition of steers for those periods was estimated by interpolation, using data of the preceding and succeeding periods. Using these assumed values for the composition of the steers during the different periods, the gain in protein and fat was readily calculated. The thermal equivalent of the protein and fat gained was calculated from data obtained by other investigators. Armsby[3e] quotes data, computed by Kohler, giving the value 5.6776 calories per gram or 2.5753 therms per pound, for protein of muscular tissue of cattle.

Fries[8] gives an average value of 9.4889 calories per gram of beef fat, or 4.3048 therms per pound.

Since no suitable control animal was available for the last two periods of Steer 528, the gains for these two periods in terms of protein and fat were not calculated, and the energy value of a pound gain was assumed to be 3,000 therms per pound. This is the value given by Armsby[3f] for animals of apparently similar condition.

The values we have used, also those published by Armsby are given in Table 6. Armsby's values are consistently higher, as is to be expected. Our animals were thin, and contained less than the usual amount of fat in the gain.

In calculating the maintenance requirements per 1,000 pounds live weight, Moulton's[9] formula was used. He has shown that

*These have not as yet been published.

TABLE 6.—ENERGY VALUE PER POUND GAIN.

Approximate age	Group I	Group II	Group III	Armsby's Values Age	Armsby's Values Energy
months	therms	therms	therms	months	therms
6	.95575	.95575	.8343	1	1.170
18	1.0918	1.0583	.9445	2-3	1.374
36	1.7136	1.1608	1.0548	5-6	1.680
54	2.1993	1.4104	1.1013	11-12	2.292
66	2.50	1.5352	1.4790	18-24	3.000
78	3.00	1.660	1.6490		

the surface areas of thin cattle are proportional to the five-eighths power of the live weight.

The average maintenance requirement of the three groups is given in Tables 7 to 10 inclusive. The summer and winter periods are given separately, and each has been calculated by two methods. One is based on dry matter consumed, the other on digestible organic nutrients consumed.

In calculating the maintenance requirement on the basis of digestible organic matter consumed, digestion coefficients were used that had been obtained at this station under similar conditions. This method is probably more accurate than the one based on dry matter consumed, and in this case gives a result somewhat higher.

During the summer months there were four periods in all in which losses in live weight occurred. In calculating averages those periods were omitted, as the results are low. It is possible that

TABLE 7.—AVERAGE DAILY MAINTENANCE REQUIREMENT DURING SUMMER PERIODS AS CALCULATED FROM DRY MATTER CONSUMED.

Steer number	Therms net energy per 1000 pounds based on 5-8 power of live weight: Group I	Group II	Group III
528—Average of 6 periods	5.870	....	....
577—Average of 3 periods	5.280	....	....
571—Average of 3 periods	5.073	....	....
579—Average of 5 periods	....	4.920	....
578—Average of 3 periods	....	3.830	....
573—Average of 3 periods	....	4.409	....
585—Average of 5 periods	....	....	4.221
575—Average of 3 periods	....	....	4.041
574—Average of 3 periods	....	....	4.302
572—Average of 3 periods	....	....	3.256
Average of each group	5.523	4.483	3.921

TABLE 8.—AVERAGE DAILY MAINTENANCE REQUIREMENT DURING WINTER MONTHS AS CALCULATED FROM DRY MATTER CONSUMED.

Steer number	Therms net energy per 1000 pounds based on 5-8 power of live weight		
	Group I	Group II	Group III
528—Average of 6 periods	5.909		
577—Average of 3 periods	5.530		
571—Average of 3 periods	5.450		
579—Average of 6 periods		4.647	
578—Average of 3 periods		3.730	
573—Average of 3 periods		4.753	
585—Average of 6 periods			4.366
575—Average of 3 periods			4.260
574—Average of 3 periods			4.673
572—Average of 3 periods			3.157
Average of each group	5.770	4.444	4.164

they are correct, but the apparently diminished requirement may be due to an incorrect assumption as to the energy value of the loss in weight. One steer, No. 585, had a navel infection during the first summer period, accompanied by a very high maintenance requirement. This period also was discarded in calculating averages.

There is a close parallel between the intake of net energy and the maintenance requirement of the animal. The record of Steer 574 for the summer periods illustrates that tendency. For the first period the average daily intake of net energy was 3.884 therms per 1,000 pounds, based on the five-eighths power of the live weight, and the maintenance requirement was 3.818 therms. For the second period the energy intake was increased to 5.783 therms, and the

TABLE 9.—AVERAGE DAILY MAINTENANCE RRQUIREMENT DURING SUMMER MONTHS AS CALCULATED FROM DIGESTIBLE ORGANIC MATTER CONSUMED.

Steer number	Therms net energy per 1000 pounds based on 5-8 power of live weight		
	Group I	Group II	Group III
528—Average of 6 periods	6.261		
577—Average of 3 periods	5.412		
571—Average of 3 periods	5.174		
579—Average of 5 periods		5.260	
578—Average of 3 periods		4.192	
573—Average of 3 periods		4.893	
585—Average of 5 periods			4.725
575—Average of 3 periods			4.454
574—Average of 3 periods			4.591
572—Average of 3 periods			3.649
Average of each group	5.777	4.869	4.408

TABLE 10.—AVERAGE DAILY MAINTENANCE REQUIREMENT DURING WINTER MONTHS AS CALCULATED FROM DIGESTIBLE ORGANIC MATTER CONSUMED

Steer number	Therms net energy per 1000 pounds based on 5-8 power of live weight		
	Group I	Group II	Group III
528	5.965		
577	5.713		
571	5.553		
579		5.071	
578		4.494	
573		5.513	
585			4.625
575			4.429
574			5.290
572			3.754
Average of each group	5.799	5.037	4.869

maintenance requirement increased to 5.119 therms. In the third period the energy intake was 5.253 therms, and the maintenance requirement was 4.836 therms.

In comparing the maintenance requirements of the three groups it should be kept in mind that Group I does not represent a high plane of nutrition. The aim was to secure maximum growth with no considerable fattening. Their maintenance requirements as computed in this paper correspond closely to the average of 22 respiration experiments by Armsby and Fries, and seven by Kellner on cattle in medium condition. A comparison of our results (computed on the basis of digestible organic matter consumed) and of those obtained by other investigators is given in Table 11.

A few facts not shown by the data seem worthy of record. Although some of the steers were receiving a very scanty ration, they apparently did not have an unusual desire for food, and some care was necessary to prevent their "getting off feed." This is especially true of the roughage, for it was impossible to induce them to consume a large quantity of hay. Any increase in the grain ration had to be very gradual.

The dentition of these steers was apparently the same as for normal animals, as regards age. So far as could be determined by observation, the temporary teeth were lost at the normal age.

Influence of Age.—The ages represented in this experiment vary from 30 days for some of the calves at the beginning of the first summer period to more than six years at the close of the seventh period. Apparently there was no relation between the age

Table 11.—Daily Maintenance Requirements of Cattle —Net Energy

No. of Experiments	Investigator	Condition of animal	Therms per 1000 lbs. live wt.		
			Maximum	Minimum	Average
	Respiration Exp's.				
22	Armsby and Fries (3b).....	Medium	7.430	4.723	5.995
7	Kellner (3b)...............	Medium	6.780	4.921	5.742
	Kellner (3b)...............	Fat	8.871	7.319	7.946
	Live Wt. Exp's.				
10	Armsby (3b)...............	Thin	7.044	6.136	6.505
3	Armsby (3b)...............	Thin	6.039	4.713	5.423
6	Haecker (3b)..............	Medium	5.676	4.662	5.021
3	Evvard (3b)...............	Medium	7.079	5.841	6.173
7	Eckles (3b)................	Medium	7.079	5.841	6.173
1	Shirky (7).................	Medium A	....	....	7.732
2	Shirky (7).................	Thin B	5.0959	4.953	5.0245
3	Our results, summer periods	Group I	7.380	4.915	5.777
3	Our results, summer periods	Group II	5.724	3.809	4.869
4	Our results, summer periods	Group III	5.217	3.276	4.408
3	Our results, winter periods.	Group I	7.431	4.314	5.799
3	Our results, winter periods.	Group II	7.598	3.246	5.037
4	Our results, winter periods.	Group III	5.574	3.475	4.869

A Corresponds to Group I animals this experiment.
B Corresponds to Group II of this experiment.

and the maintenance requirement of these animals. Some of the steers showed a gradual decrease in the maintenance cost from the beginning to the end of the experiment. In such cases it was found that the energy intake per 1,000 pounds had also decreased. On the other hand, steers with an increasing energy intake showed an increased maintenance requirement. Maintenance trials on young animals usually give higher results than have been obtained with mature animals, but if age does influence the maintenance requirement the effect is too slight to be shown in a live weight experiment of this kind.

Influence of Season.—The maintenance requirement of the steers in Groups I and II is slightly higher during the winter, as compared to the summer months. The animals in Group III however required considerably more energy for maintenance during the winter periods than they did in the summer periods. Presumably the energy expenditure incident to the greater consumption of feed by the steers of Groups I and II is sufficiently great to make unnecessary the oxidation of a large quantity of additional nutrients during the winter months in order to maintain the body temperature. This is not the case with the steers on a lower nutritional plane, and so during periods of prevailingly low temperatures they

must oxidize a larger amount of material in order to counteract the more rapid loss of heat from the body surface. The contrast between the two seasons is shown in Table 12.

Table 12.—Daily Maintenance Requirement in Therms of Cattle During Summer and Winter Months.

During Summer and Winter Months			
Calculated on basis of digestible organic matter consumed			
	Group I	Group II	Group III
Summer	5.777	4.869	4.408
Winter	5.779	5.037	4.869
Calculated on basis of dry matter consumed			
Summer	5.523	4.483	3.921
Winter	5.770	4.444	4.164
Average of results obtained by the two methods			
Summer	5.650	4.676	4.165
Winter	5.775	4.741	4.517

SUMMARY AND DISCUSSION

There is a close relation between the amount of net energy consumed and the maintenance requirement. Periods of high energy intake were periods of high maintenance cost, while periods of low energy intake were accompanied by a lowered maintenance requirement.

The averages of all periods show the following daily maintenance requirements per 1,000 pounds live weight, in terms of net energy. Summer months: Group I, (high plane) 5.650 therms; Group II, (medium plane) 4.676 therms; Group III, (low plane) 4.165 therms. Winter months: Group I, 5.775 therms; Group II, 4.741 therms; Group III, 4.517 therms.

The maintenance requirement of Group I is about 20 percent higher than that of Group II, and about 30 percent higher than that of Group III.

If there is a definite relation between the age of animals and their maintenance requirements, it was obscured in this investigation by variations in the food intake.

The maintenance requirement of these animals is higher in the winter than in the summer.

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ORIGINAL DATA AND CALCULATIONS IN DETAIL

TABLE 13.—WEIGHT IN POUNDS OF ANIMALS, AND OF FEED CONSUMED BY THIRTY DAY PERIODS

Date beginning of period	Period No.	Live° weight Pounds	Grain Pounds	Hay Pounds	Milk Pounds	Date beginning of period	Period No.	Live° weight Pounds	Grain Pounds	Hay Pounds
Steer 585						**585 (Cont.)**				
5-22-14	1	143.1	....	8.75	321	8- 5-17	40	495	15.0	220.5
6-21-14	2	155	5.00	15.5	317.5	9- 4-17	41	498	37.0	225.0
7-21-14	3	173	....	59.5	300	10- 4-17	42	512	70.0	225.0
8-20-14	4	188	....	90.0	300	11- 3-17	43	529	67.0	232.0
9-19-14	5	194	....	104.0	299.8	12- 3-17	44	532	72.5	240.0
10-18-14	6	200	....	120.0	290.0	1- 2-18	45	554	76.0	240.0
11-18-14	7	192	....	140.0	100.0	2- 1-18	46	576	36.5	240.0
12-18-14	8	198	....	150.0	......	3- 3-18	47	586	50.0	236.0
1-17-15	9	193	....	150.0	......	4- 2-18	48	576	....	225.0
2-16-15	10	194	....	150.0	......	5- 2-18	49	596	....	224.5
3-18-15	11	218	....	150.0	......	6- 1-18	50	578	....	240.0
4-17-15	12	223	....	150.0	......	7- 1-18	51	568	....	240.0
5-17-15	13	229	....	150.0	......	7-31-18	52	554	....	240.0
6-16-15	14	233	....	155.0	......	8-30-18	53	542	....	253.0
7-17-15	15	235	11.75	153.5	......	9-29-18	54	532	....	255.0
8-16-15	16	251	36.7	163.5	......	10-29-18	55	506	....	263.5
9-15-15	17	256	47.0	150.5	......	11-28-18	56	532	....	278.0
10-14-15	18	272	60.0	154.0	......	12-28-18	57	558	....	328.5
11-14-15	19	290	60.0	180.0	......	1-27-19	58	562	....	317.0
12-14-15	20	303	60.0	180.0	......	2-26-19	59	591	....	330.0
1-13-16	21	312	60.0	180.0	......	3-28-19	60	603	....	330.0
2-12-16	22	337	56.5	180.0	......	4-27-19	61	604	....	317.5
3-13-16	23	345	34.0	180.0	......	5-27-19	62	614	....	326.5
4-12-16	24	356	30.0	180.0	......	6-26-19	63	622	....	335.0
5-12-16	25	360	30.0	180.0	......	7-26-19	64	643	....	360.0
6-11-16	26	361	31.5	180.0	......	8-25-19	65	630	....	360.0
7-11-16	27	370	45.0	180.0	......	9-24-19	66	645	31.4	316.5
8-10-16	28	387	45.0	180.0	......	10-24-19	67	653	60.0	333.0
9- 9-16	29	386	42.5	170.0	......	11-23-19	68	688	58.0	257.5
10- 9-16	30	403	45.0	187.5	......	12-23-19	69	682	60.0	334.0
11- 8-16	31	413	45.0	201.0	......	1-22-20	70	716	60.0	360.0
12- 8-16	32	419	51.0	211.5	......	2-21-20	71	741	60.0	360.0
1- 7-17	33	437	75.0	225.0	......	3-22-20	72	763	60.0	360.0
2- 6-17	34	465	66.0	218.5	......	4-21-20	73	785	60.0	360.0
3- 8-17	35	484	55.0	210.0	......	5-21-20	74	825	60.0	359.0
4- 7-17	36	482	38.0	210.0	......	6-20-20	75	850	60.0	360.0
5- 7-17	37	496	30.0	210.0	......	7-20-20	76	858	60.0	359.0
6- 6-17	38	499	25.0	210.5	......	8-19-20	77	878	60.0	360.0
7- 6-17	39	504	15.0	208.5	......	9-18-20	78	885	60.0	360.0
Steer 579						**579 (Cont.)**				
5-30-14	1	154.0	....	2.55	226	8- 5-17	40	709	75.0	225.0
6-21-14	2	183.9	7.3	14.5	374	9- 4-17	41	707	86.0	225.0
7-21-14	3	204.6	24.0	47.0	420	10- 4-17	42	725	141.5	231.0
8-20-14	4	240.0	30.0	60.5	208	11- 3-17	43	744	136.5	247.5
9-19-14	5	270	37.0	74.0	420	12- 3-17	44	758	147.0	251.5
10-18-14	6	304	45.0	90.0	420	1- 2-18	45	789	164.5	253.0
11-18-14	7	305	45.0	103.0	140	2- 1-18	46	820	120.0	255.0
12-18-14	8	316	45.0	120.0	......	3- 3-18	47	822	67.0	255.0
1-17-15	9	321	45.0	120.0	......	4- 2-18	48	831	73.5	255.5
2-16-15	10	322	45.0	122.0	......	5- 2-18	49	851	22.5	292.5
3-18-15	11	335	45.0	120.0	......	6- 1-18	50	834.5	....	309.0

°Average weight of last ten days of period.

TABLE 13 (Continued).—WEIGHT IN POUNDS OF ANIMALS AND OF FEED CONSUMED BY THIRTY DAY PERIODS

Date beginning of period	Period No.	Live° weight *Pounds*	Grain *Pounds*	Hay *Pounds*	Milk *Pounds*	Date beginning of period	Period No.	Live° weight *Pounds*	Grain *Pounds*	Hay *Pounds*
Steer 579	**(Cont.)**					**Steer 579**	**(Cont.)**			
4-17-15	12	334	45.0	120.0	......	7- 1-18	51	821	....	315.0
5-17-15	13	344	45.0	120.0	......	7-31-18	52	786	....	315.0
6-16-15	14	344	50.0	120.0	......	8-30-18	53	788	26.0	330.0
7-17-15	15	351	71.5	143.0	......	9-29-18	54	781	2.0	339.0
8-16-15	16	379	76.25	178.0	......	10-29-18	55	705	....	253.0
9-15-15	17	399	70.0	180.0	......	11-28-18	56	730	....	304.5
10-14-15	18	409	60.0	180.0	......	12-28-18	57	750	....	330.0
11-14-15	19	419	64.5	184.5	......	1-27-19	58	750	....	351.5
12-14-15	20	430	76.5	194.0	......	2-26-19	59	780	....	360.0
1-13-16	21	434	75.0	195.0	......	3-28-19	60	788	....	360.0
2-12-16	22	453	75.0	195.0	......	4-27-19	61	808	....	357.0
3-13-16	23	469	75.0	195.0	......	5-27-19	62	729	....	287.0
4-12-16	24	489	75.0	195.0	......	6-26-19	63	776	....	326.0
5-12-16	25	495	74.0	194.0	......	7-26-19	64	799	....	359.0
6-11-16	26	505	68.0	180.0	......	8-25-19	65	776	....	360.0
7-11-16	27	521	75.0	180.0	......	9-24-19	66	766	8.5	360.0
8-10-16	28	536	75.0	180.0	......	10-24-19	67	771	59.0	360.0
9- 9-16	29	552	75.0	180.0	......	11-25-19	68	782	60.0	360.0
10- 9-16	30	557	75.0	187.5	......	12-23-19	69	797	60.0	329.5
11- 8-16	31	565	81.0	189.0	......	1-22-20	70	823	60.0	360.0
12- 8-16	32	560	90.0	200.0	......	2-21-20	71	843	60.0	360.0
1- 7-17	33	582	90.0	216.0	......	3-22-20	72	855	60.0	360.0
2- 6-17	34	601	93.0	211.0	......	4-21-20	73	857	60.0	360.0
3- 8-17	35	632	105.0	225.0	......	5-21-20	74	866	59.0	328.0
4- 7-17	36	653	95.5	224.5	......	6-20-20	75	893	60.0	360.0
5- 7-17	37	674	94.0	229.5	......	7-20-20	76	910	60.0	358.0
6- 6-17	38	701	91.5	224.5	......	8-19-20	77	907	60.0	360.0
7- 6-17	39	708	75.0	225.0	......	9-19-20	78	918	60.0	360.0
Steer 528						**528 (Cont.)**				
6-11-14	1	179.0	....	2.5	124.9	8- 5-17	40	1008	188.0	227.0
6-21-14	2	202.8	14.0	14.0	489	9- 4-17	41	1029	196.0	238.0
7-21-14	3	252.0	44.0	53.5	582	10- 4-17	42	1043	209.0	231.0
8-20-14	4	303.8	69.0	75.0	600	11- 3-17	43	1070	218.0	240.0
9-19-14	5	363.8	110.5	101.5	600	12- 3-17	44	1076	225.0	240.0
10-18-14	6	425.1	120.0	120.0	600	1- 2-18	45	1080	225.0	240.0
11-18-14	7	426.8	105.2	120.0	176	2- 1-18	46	1178	225.0	240.0
12-18-14	8	439.4	120.0	120.0	......	3- 3-18	47	1147	225.0	240.0
1-17-15	9	457.2	120.0	120.0	......	4- 2-18	48	1163	224.5	240.5
2-16-15	10	460.6	120.0	119.0	......	5- 2-18	49	1184	150.0	293.5
3-18-15	11	482	120.0	120.0	......	6- 1-18	50	1177	97.0	318.0
4-17-15	12	497	120.0	120.0	......	7- 1-18	51	1159	28.0	330.0
5-17-15	13	507	120.0	120.0	......	7-31-18	52	1139	30.0	330.0
6-16-15	14	517	120.0	130.0	......	8-30-18	53	1122	30.0	330.0
7-17-15	15	527	120.0	150.0	......	9-29-18	54	1107	30.0	336.0
8-16-15	16	559	145.7	152.0	......	10-29-18	55	1103	87.0	333.0
9-15-15	17	586	150.0	180.0	......	11-28-18	56	1122	120	353.5
10-14-15	18	620	150.0	180.0	......	12-28-18	57	1155	120.0	357.5
11-14-15	19	629	155.0	184.5	......	1-27-19	58	1158	120.0	360.0
12-14-15	20	651	165.0	195.0	......	2-26-19	59	1172	150.5	360.0
1-13-16	21	659	165.0	195.0	......	3-28-19	60	1211	150.0	360.0
2-12-16	22	678	165.0	195.0	......	4-27-19	61	1231	150.0	360.0

°Average weight of last ten days of period.

Table 13 (Continued).—Weight in Pounds of Animals and of Feed Consumed by Thirty Day Periods

Date beginning of period	Period No.	Live° weight *Pounds*	Grain *Pounds*	Hay *Pounds*	Milk *Pounds*	Date beginning of period	Period No.	Live° weight *Pounds*	Grain *Pounds*	Hay *Pounds*
Steer 528	**(Cont.)**					**Steer 528**	**(Cont.)**			
3–13–16	23	699	165.0	195.0	......	5–27–19	62	1258	150.0	360.0
4–12–16	24	727	165.0	195.0	......	6–26–19	63	1244	149.0	357.0
5–12–16	25	745	165.0	195.0	......	7–26–19	64	1267	150.0	360.0
6–11–16	26	768	165.0	194.5	......	8–25–19	65	1278	150.0	360.0
7–11–16	27	785	165.0	180.0	......	9–24–19	66	1278	150.0	360.0
8–10–16	28	805	165.0	180.5	......	10–24–19	67	1274	150.0	360.0
9– 9–16	29	837	179.5	189.0	......	11–23–19	68	1285	148.5	360.0
10– 9–16	30	869	180.0	202.5	......	12–23–19	69	1304	150.0	360.0
11– 8–16	31	881	180.0	211.0	......	1–22–20	70	1314	150.0	360.0
12– 8–16	32	878	180.0	214.5	......	2–21–20	71	1333	150.0	360.0
1– 7–17	33	887	180.0	226.0	......	3–22–20	72	1342	150.0	360.0
2– 6–17	34	915	180.0	225.0	......	4–21–20	73	1341	150.0	360.0
3– 8–17	35	933	180.0	225.5	......	5–21–20	74	1355	150.0	360.0
4– 7–17	36	942	180.0	225.0	......	6–20–20	75	1367	150.0	360.0
5– 7–17	37	964	190.0	228.5	......	7–20–20	76	1369	150.0	360.0
6– 6–17	38	986	180.0	225.0	......	8–19–20	77	1381	147.0	348.0
7– 6–17	39	990	180.0	225.0	......	9–19–20	78	1401	150.0	360.0

Date beginning of period	Period No.	Live° weight *Pounds*	Grain *Pounds*	Hay *Pounds*	Milk *Pounds*	Period No.	Live° weight *Pounds*	Grain *Pounds*	Hay *Pounds*	Milk *Pounds*
Steer 578						**Steer**	**577**			
8– 5–17	1	252	25.0	99.5	152.5	1	249	23.5	79.4	240.0
9– 4–17	2	268	44.3	111.0	216.4	2	272	33.0	104.1	236
10– 4–17	3	279	72.2	130.8	54.5	3	288	71.1	118.2	67.5
11– 8–17	4	314	90.0	140.4	....	4	317	94.9	140.4	....
12– 3–17	5	317	76.1	194.0	....	5	339	105.0	194.4	....
1– 2–18	6	331	81.0	164.5	....	6	361	105.5	164.5	....
2– 1–18	7	365	81.6	165.0	....	7	404	107.5	165.0	....
3– 3–18	8	383	29.0	164.0	....	8	441	120.0	165.0	....
4– 2–18	9	378	21.5	165.5	....	9	472	119.5	165.5	....
5– 2–18	10	411	10.0	192.0	....	10	504	91.5	195.0	....
6– 1–18	11	418	....	196.0	....	11	524	90.0	198.5	....
7– 1–18	12	413	....	195.0	....	12	538	90.0	210.0	....
7–31–18	13	402	....	195.0	....	13	555	90.0	210.0	....
8–30–18	14	393	....	208.0	....	14	560	90.0	223.0	....
9–29–18	15	383	....	210.0	....	15	578	90.0	225.0	....
10–29–18	16	372	2.0	210.0	....	16	599	113.0	211.5	....
11–28–18	17	375	....	233.5	....	17	617	120.0	210.0	....
12–28–18	18	395	....	226.5	....	18	640	120.0	210.0	....
1–27–19	19	409	....	240.0	....	19	671	120.0	231.0	....
2–26–19	20	432	....	240.0	....	20	690	120.0	240.0	....
3–28–19	21	438	....	240.0	....	21	730	120.0	240.0	....
4–27–19	22	455	....	240.0	....	22	750	119.0	228.5	....
5–27–19	23	458	....	241.5	....	23	764	120.0	240.0	....
6–26–19	24	457	....	245.0	....	24	778	120.0	240.0	....
7–26–19	25	466	17.0	269.0	....	25	813	119.0	240.0	....
8–25–19	26	490	30.0	270.0	....	26	820	120.0	239.0	....
9–24–19	27	496	30.5	270.0	....	27	810	107.5	226.5	....

°Average weight of last ten days of period.

TABLE 13 (Continued).—WEIGHT IN POUNDS OF ANIMALS AND OF FEED CONSUMED BY THIRTY DAY PERIODS

Date beginning of period	Period No.	Live° weight *Pounds*	Grain *Pounds*	Hay *Pounds*	Milk *Pounds*	Period No.	Live° weight *Pounds*	Grain *Pounds*	Hay *Pounds*	Milk *Pounds*
Steer 578	(Cont.)					**Steer**	**577 (Cont.)**			
10–24–19	28	512	30.0	270.0	....	28	833	120.0	258.0	....
11–23–19	29	519	30.0	270.0	....	29	855	120.0	270.0	....
12–23–19	30	541	30.0	270.0	....	30	875	120.0	270.0	....
1–22–20	31	555	30.0	270.0	....	31	905	120.0	270.0	....
2–21–20	32	580	30.0	270.0	....	32	915	120.0	270.0	....
3–22–20	33	595	30.0	270.0	....	33	941	120.0	270.0	....
4–21–20	34	580	30.0	270.0	....	34	957	120.0	270.0	....
5–21–20	35	591	30.0	270.0	....	35	966	120.0	270.0	....
6–20–20	36	696	30.0	270.0	....	36	976	120.0	270 0	....
7–20–20	37	613	30.0	270.0	....	37	995	120.0	270.0	....
8–19–20	38	603	30.0	270.0	....	38	990	120.0	270.0	....
9–18–20	39	619	30.0	270.0	....	39	1000	120.0	270.0	....
Steer 575						**Steer**	**574**			
8– 5–17	1	217	13.4	75.8	2.35	1	242	18.0	78.6	240.0
9– 4–17	2	227	.2	75.0	236 5	2	244	9.8	90.0	226.9
10– 4–17	3	228	....	109.0	67.0	3	252	23.4	126.2	62.5
11– 3–17	4	237	17.1	135.0	....	4	264	45.0	141.0	....
12– 3–17	5	246	30.0	143.9	....	5	268	46.5	150.0	....
1– 2–18	6	257	30.0	164.5	....	6	284	51.0	164.5	....
2– 1–18	7	275	18.3	165.0	....	7	309	51.2	165.0	....
3– 3–18	8	283	....	155.0	....	8	315	11.5	165.0	....
4– 2–18	9	290	....	150.0	....	9	315	5.5	165.0	....
5– 2–18	10	308	....	150.0	....	10	337	....	174.0	....
6– 1–18	11	304	....	150.0	....	11	337	....	174.0	....
7– 1–18	12	307	....	150.0	....	12	332	....	180.0	....
7–31–18	13	294	....	150.0	....	13	322	....	180.0	....
8–30–18	14	298	....	161.5	....	14	324	....	193.0	....
9–29–18	15	299	....	165.0	....	15	321	....	195.0	....
10–29–18	16	294	27.5	152.5	....	16	316	....	210.5	....
11–28–18	17	295	53.5	151.0	....	17	309	32.5	192.5	....
12–28–18	18	308	59.0	148.0	....	18	321	60.0	175.5	....
1–27–19	19	328	60.0	150.0	....	19	333	60.0	180.0	....
2–26–19	20	343	60.0	150.0	....	20	348	60.0	180.0	....
3–28–19	21	358	60.0	150.0	....	21	368	60.0	180.0	....
4–27–19	22	380	60.0	150.0	....	22	382	60.0	180.0	....
5–27–19	23	394	60.0	154.0	....	23	412	60.0	180.0	....
6–26–19	24	409	60.0	179.0	....	24	417	60.0	180.0	....
7–26–19	25	426	60.0	180.0	....	25	445	60.0	180.0	....
8–25–19	26	425	60.0	180.0	....	26	445	60.0	180.0	....
9–24–19	27	436	60.0	180.0	....	27	432	60.0	180.0	....
10–24–19	28	441	60.0	180.0	....	28	439	60.0	180.0	....
11–23–19	29	447	60.0	180.0	....	29	435	60.0	180.0	....
12–23–19	30	458	60.0	180.5	....	30	448	60.0	180.5	....
1–22–20	31	472	60.0	180.0	....	31	453	60.0	180.0	....
2–21–20	32	480	60.0	180.0	....	32	464	60.0	180.0	....
3–22–20	33	496	60.0	180.0	....	33	474	60.0	180.0	....
4–21–20	34	504	60.0	180.0	....	34	481	60.0	180.0	....
5–21–20	35	515	60.0	180.0	....	35	499	60.0	180.0	....
6–20–20	36	528	60.0	180.0	....	36	511	60.0	180.0	....
7–20–20	37	538	60.0	180.0	....	37	518	60.0	180.0	....
8–19–20	38	530	60.0	180.0	....	38	506	60.0	180.0	....
9–18–20	39	537	60.0	180.0	....	39	518	60.0	180.0	....

°Average weight of last ten days of period.

TABLE 13 (Continued).—WEIGHT IN POUNDS OF ANIMALS AND OF FEED CONSUMED BY THIRTY DAY PERIODS

Date beginning of period	Period No.	Live weight *Pounds*	Grain *Pounds*	Hay *Pounds*	Milk *Pounds*	Period No.	Live weight *Pounds*	Grain *Pounds*	Hay *Pounds*	Milk *Pounds*
Steer 573						**Steer**	**572**			
8- 5-17	1	197	14.1	64.9	214.0	1	210	16.4	72.6	215.4
9- 4-17	2	220	34.1	102.3	253.0	2	216	22.1	92.1	42.3
10- 4-17	3	237	75.7	108.4	50.5	3	231	28.8	124.9	....
11- 3-17	4	269	105.8	128.1	....	4	243	30.0	134.5	....
12- 3-17	5	290	87.5	145.4	....	5	252	30.0	146.5	....
1- 2-18	6	312	72.0	164.3	....	6	263	30.0	150.0	....
2- 1-18	7	335	62.5	165.0	....	7	280	16.3	154.5	....
3- 3-18	8	345	30.0	165.0	....	8	289	....	155.0	....
4- 2-18	9	354	29.5	165.6	....	9	295	0.5	150.0	....
5- 2-18	10	366	15.0	192.0	....	10	305	....	150.0	....
6- 1-18	11	364	6.0	202.5	....	11	307	....	150.0	....
7- 1-18	12	369	....	210.0	....	12	311	....	150.0	....
7-31-18	13	355	....	210.0	....	13	306	....	150.0	....
8-30-18	14	367	....	223.0	....	14	304	....	165.0	....
9-29-18	15	364	....	225.0	....	15	309	....	165.0	....
10-29-18	16	361	....	213.5	....	16	309	....	179.0	....
11-28-18	17	339	9.5	167.5	....	17	304	....	182.0	....
12-28-18	18	354	30.0	180.5	....	18	309	....	180.0	....
1-27-19	19	383	30.0	221.5	....	19	317	....	187.0	....
2-26-19	20	399	30.0	221.5	....	20	328	....	210.0	....
3-28-19	21	406	43.0	213.5	....	21	341	....	210.0	....
4-27-19	22	431	60.0	210.0	....	22	358	....	210.0	....
5-27-19	23	438	60.0	212.5	....	23	362	....	206.0	....
6-26-19	24	454	60.0	217.5	....	24	370	....	210.5	....
7-26-19	25	477	60.0	209.0	....	25	375	....	210.0	....
8-25-19	26	492	60.0	210.0	....	26	380	....	210.0	....
9-24-19	27	485	60.0	206.0	....	27	378	....	210.0	....
10-24-19	28	499	60.0	200.5	....	28	375	....	210.0	....
11-23-19	29	503	60.0	210.5	....	29	372	....	224.5	....
12-23-19	30	522	60.0	209.5	....	30	392	....	241.5	....
1-22-20	31	532	60.0	210.0	....	31	414	....	254.0	....
2-21-20	32	537	60.0	210.0	....	32	434	....	270.0	....
3-22-20	33	552	60.0	210.0	....	33	448	....	270.0	....
4-21-20	34	557	60.0	210.0	....	34	433	....	238.5	....
5-21-20	35	569	60.0	210.0	....	35	460	....	270.0	....
6-20-20	36	581	60.0	210.0	....	36	469	....	270.0	....
7-20-20	37	595	60.0	210.0	....	37	479	....	270.0	....
8-19-20	38	588	60.0	210.0	....	38	485	....	270.0	....
9-18-20	39	594	60.0	209.5	....	39	488	....	270.0	....
Steer 571										
8- 5-17	1	173	24.5	79.3	82.8	....	....	....	....	....
9- 4-17	2	181	32.5	103.0	....	....	....	....	....	....
10- 4-17	3	200	81.1	96.9	....	....	....	....	....	....
11- 3-17	4	237	109.6	111.0	....	....	....	....	....	....
12- 3-17	5	264	105.9	123.3	....	....	....	....	....	....
1- 2-18	6	288	102.0	134.8	....	....	....	....	....	....
2- 1-18	7	321	102.0	136.5	....	....	....	....	....	....
3- 3-18	8	355	102.0	135.0	....	....	....	....	....	....
4- 2-18	9	383	103.0	142.0	....	....	....	....	....	....
5- 2-18	10	412	76.0	177.5	....	....	....	....	....	....
6- 1-18	11	433	70.0	189.0	....	....	....	....	....	....

TABLE 13 (Continued).—WEIGHT IN POUNDS OF ANIMALS AND OF FEED CONSUMED BY THIRTY DAY PERIODS

Date beginning of period	Period No.	Live weight *Pounds*	Grain *Pounds*	Hay *Pounds*	Milk *Pounds*	Period No.	Live weight *Pounds*	Grain *Pounds*	Hay *Pounds*	Milk *Pounds*
Steer 571	**(Cont.)**									
7- 1-18	12	453	75.0	195.0						
7-31-18	13	469	75.0	195.0						
8-30-18	14	478	75.0	208.0						
9-29-18	15	483	75.0	210.0						
10-29-18	16	494	88.5	210.5						
11-28-18	17	499	90.0	163.0						
12-28-18	18	510	90.0	180.5						
1-27-19	19	536	90.0	207.0						
2-26-19	20	559	90.0	210.0						
3-28-19	21	502	90.5	210.0						
4-27-19	22	496	90.0	210.0						
5-27-19	23	612	90.0	210.0						
6-26-19	24	616	88.5	206.5						
7-26-19	25	635	90.0	210.0						
8-25-19	26	637	89.9	210.0						
9-24-19	27	617	90.0	213.0						
10-24-19	28	627	90.0	230.0						
11-23-19	29	649	90.0	242.0						
12-23-19	30	667	90.0	240.0						
1-22-20	31	681	88.5	228.5						
2-21-20	32	699	90.0	240.0						
3-22-20	33	716	90.0	240.0						
4-21-20	34	727	90.0	240.0						
5-21-20	35	747	90.0	240.0						
6-20-20	36	755	90.0	240.0						
7-20-20	37	754	90.0	240.0						
8-19-20	38	752	90.0	240.0						
9-18-20	39	757	90.0	240.0						

TABLE 14.—DRY MATTER AND ORGANIC MATTER IN FEED BY 30-DAY PERIODS

Period	Dry matter in grain *Pounds*	Dry matter in hay *Pounds*	Organic matter in grain *Pounds*	Organic matter in hay *Pounds*	Total organic matter *Pounds*	Digestible organic matter *Pounds*
Steer 585						
1	....	8.020	....	7.655	7.655	4.464
2	4.714	14.211	4.548	18.107	13.559	11.480
3	....	53.811	....	48.683	48.683	28.392
4	....	84.158	....	67.090	76.090	44.376
5	....	97.228	....	87.906	87.906	51.267
6	26.974	111.024	....	100.449	100.449	58.582
7	....	127.800	....	115.769	115.769	67.516
8	....	136.098	....	123.498	123.498	72.024
9	....	136.098	....	123.498	123.498	72.024
10	....	136.098	....	123.498	123.498	72.024
11	....	136.098	....	123.498	123.498	72.024
12	....	136.098	....	123.498	123.498	72.024
13	....	136.098	....	123.498	123.498	72.024
14	....	144.047	....	131.017	131.017	76.409
15	10.616	142.540	10.231	129.640	139.871	84.342
16	33.196	151.424	31.983	138.174	170.157	102.605
17	61.760	139.866	60.208	138.656	188.864	113.885
18	54.639	143.105	52.691	129.375	182.066	115.430
19	54.330	167.263	52.394	51.213	103.617	65.687
20	53.710	168.654	51.810	152.515	204.324	129.542
21	53.724	178.837	51.847	162.701	214.548	136.023
22	50.568	164.763	48.801	148.733	197.534	125.236
23	30.431	164.763	29.311	148.733	178.044	110.904
24	27.072	165.125	26.013	149.135	175.148	109.100
25	27.072	165.125	26.013	149.135	175.148	109.100
26	28.422	164.641	27.311	157.199	184.510	114.931
27	40.609	166.170	39.021	152.310	191.331	121.304
28	40.609	166.170	39.021	152.310	191.331	121.304
29	38.357	156.923	36.857	143.843	180.700	114.564
30	40.228	172.617	38.630	158.217	196.837	124.795
31	39.846	185.540	38.217	170.070	208.287	132.054
32	45.156	193.915	43.311	176.576	219.887	139.408
33	66.404	207.059	63.690	187.969	251.659	159.552
34	58.432	201.112	56.044	182.562	238.606	151.276
35	48.702	193.255	46.712	175.435	222.147	140.841
36	33.684	193.255	32.324	175.435	207.759	129.413
37	26.769	193.255	25.721	175.435	201.156	125.300
38	22.343	193.255	21.477	175.435	196.912	118.738
39	13.406	191.933	12.886	174.233	187.119	112.833
40	13.406	202.915	12.886	184.205	197.091	118.846
41	33.063	207.059	31.781	187.969	219.750	136.882
42	62.557	210.216	60.132	191.418	251.550	159.483
43	59.770	218.126	57.487	198.876	256.363	162.534
44	64.609	221.997	62.164	201.753	263.917	167.323
45	67.736	219.940	65.172	199.900	265.072	168.056
46	32.538	219.940	31.307	199.900	231.207	144.019
47	44.566	215.383	42.880	195.753	238.633	151.283
48	....	207.593	....	187.163	187.163	109.143
49	....	206.844	....	187.950	187.950	109.612
50	....	219.508	....	199.066	199.066	116.095
51	....	222.130	....	197.050	197.050	114.920
52	....	222.130	....	197.050	197.050	114.920
53	....	234.484	....	208.361	208.361	121.516

TABLE 14 (Continued).—DRY MATTER AND ORGANIC MATTER IN FEED BY 30-DAY PERIODS

Period	Dry matter in grain *Pounds*	Dry matter in hay *Pounds*	Organic matter in grain *Pounds*	Organic matter in hay *Pounds*	Total organic matter *Pounds*	Digestible organic matter *Pounds*
Steer 585 (Cont.)						
54	....	236.436	....	210.176	210.176	122.575
55	....	243.117	....	215.919	215.919	125.924
56	....	244.898	....	215.688	215.688	125.789
57	....	289.470	....	254.970	254.970	148.698
58	....	279.340	....	246.020	246.020	143.479
59	....	290.748	....	256.060	256.060	143.502
60	....	290.740	....	256.060	256.060	149.354
61	....	281.412	....	249.172	249.172	145.317
62	....	291.199	....	260.959	260.959	152.191
63	....	297.227	....	267.117	267.117	155.783
64	....	319.520	....	287.150	287.150	167.466
65	....	319.520	....	287.150	287.150	167.466
66	27.663	280.876	26.661	252.426	279.087	168.298
67	52.877	304.072	50.961	275.429	326.390	196.813
68	51.105	275.950	49.254	254.840	304.094	192.796
69	53.460	297.126	51.281	269.746	321.027	199.968
70	53.460	320.353	51.281	290.853	342.134	213.115
71	53.460	320.353	51.281	290.853	342.134	213.115
72	53.460	320.353	51.281	290.853	342.134	213.115
73	54.787	320.353	51.513	290.853	342.366	283.260
74	55.552	319.243	53.227	289.813	343.040	213.680
75	55.552	320.353	53.227	290.853	344.080	214.327
76	55.552	324.764	53.227	294.509	347.836	216.667
77	55.552	338.393	53.227	305.928	358.155	223.095
78	53.233	338.393	50.292	305.928	355.221	221.267
Steer 579						
1	....	2.337	....	2.230	2.230	1.301
2	6.835	13.297	6.595	12.687	19.289	12.406
3	21.317	41.92	20.434	37.937	58.371	37.556
4	26.663	56.577	25.563	51.153	76.716	49.359
5	33.813	69.177	32.228	62.544	94.772	60.976
6	39.738	82.904	38.192	75.032	113.224	72.848
7	39.738	66.513	38.172	57.667	95.839	61.662
8	39.738	108.874	38.192	98.804	136.996	88.143
9	40.674	108.874	39.156	98.804	137.960	88.763
10	40.614	110.697	39.152	100.447	139.599	89.817
11	40.614	108.874	39.152	98.804	137.956	88.761
12	40.614	108.874	39.152	98.804	137.956	88.761
13	40.614	108.874	39.152	98.804	137.956	88.761
14	45.162	114.739	43.540	104.549	148.189	95.345
15	64.604	132.805	62.276	120.795	183.071	117.788
16	68.975	168.623	66.455	154.178	220.633	141.955
17	61.512	167.275	59.199	153.855	213.054	137.079
18	54.639	167.253	52.691	151.213	203.904	131.191
19	58.361	171.440	56.282	155.000	211.282	133.953
20	68.488	180.275	66.066	162.906	228.972	147.321
21	67.142	179.823	64.796	162.344	227.140	146.142
22	67.142	178.459	64.796	161.099	225.895	145.341
23	67.129	178.459	64.642	161.099	225.741	145.242
24	67.677	179.865	65.031	161.545	226.576	145.779
25	66.766	177.97	64.155	160.730	224.885	144.691

TABLE 14 (Continued).—DRY MATTER AND ORGANIC MATTER IN FEED BY 30-DAY PERIODS

Period	Dry matter in grain *Pounds*	Dry matter in hay *Pounds*	Organic matter in grain *Pounds*	Organic matter in hay *Pounds*	Total organic matter *Pounds*	Digestible organic matter *Pounds*
Steer 579 (Cont.)						
26	61.361	165.772	58.961	151.134	210.095	135.175
27	67.677	166.17	65.031	152.310	217.341	139.837
28	67.677	166.17	65.031	152.31	217.341	139.837
29	67.677	166.17	65.031	152.31	217.341	139.837
30	73.553	173.084	70.868	158.654	229.523	147.675
31	71.727	174.565	68.796	159.945	228.741	147.171
32	79.687	184.228	76.431	167.765	244.196	157.116
33	79.687	198.794	76.431	180.464	256.895	165.286
34	82.341	194.189	78.976	176.279	255.255	164.231
35	92.967	207.059	89.168	187.969	277.137	178.309
36	84.667	206.591	81.239	187.541	268.770	172.927
37	83.882	211.187	80.602	191.717	272.319	175.210
38	81.771	206.591	78.600	187.541	266.141	171.235
39	67.068	207.059	64.469	187.969	252.438	160.046
40	67.068	207.059	64.469	187.969	252.438	160.046
41	76.865	207.059	73.885	187.261	261.854	166.015
42	126.453	215.797	121.550	196.499	318.049	204.633
43	121.745	232.210	117.109	211.670	328.779	211.536
44	131.020	232.557	126.062	211.336	337.398	217.082
45	146.614	231.830	141.067	210.700	351.767	226.327
46	106.958	233.635	102.910	212.335	315.245	202.829
47	59.722	233.635	57.462	212.335	269.797	171.051
48	65.942	235.717	63.459	212.527	275.986	174.975
49	20.256	269.474	19.495	244.911	264.406	159.437
50	....	282.572	....	256.351	256.351	149.504
51	....	291.554	....	258.634	258.634	150.835
52	....	291.554	....	258.634	258.634	150.835
53	23.476	308.734	22.572	274.357	296.929	179.048
54	1.805	314.352	1.736	279.442	281.178	163.983
55	....	233.442	....	207.339	207.339	120.920
56	....	268.290	....	236.290	236.290	137.805
57	....	290.760	....	256.080	256.080	149.346
58	....	309.700	....	272.760	272.760	159.074
59	....	278.747	....	240.907	240.907	140.497
60	....	278.747	....	240.907	240.907	140.497
61	....	316.923	....	280.723	280.723	163.718
62	....	256.276	....	229.544	229.544	133.870
63	....	289.234	....	259.924	259.924	151.588
64	....	318.530	....	286.250	285.250	166.941
65	....	319.620	....	287.150	287.150	167.466
66	7.489	19.520	7.218	287.150	294.368	171.675
67	51.991	320.059	50.107	289.896	340.003	198.290
68	53.442	317.243	51.279	287.753	339.032	211.183
69	53.460	293.057	51.281	266.047	317.328	197.664
70	53.460	293.057	51.281	266.047	317.328	197.664
71	53.460	293.057	51.281	266.047	317.328	197.664
72	53.460	293.057	51.281	266.047	317.328	197.664
73	54.556	317.243	52.576	287.753	340.329	205.218
74	54.629	291.776	52.340	264.906	317.246	191.299
75	55.555	325.603	53.227	295.275	348.502	210.147
76	55.555	338.393	53.227	305.928	359.155	216.570
77	55.555	338.393	53.227	305.928	359.155	216.570
78	53.233	338.393	50.293	305.928	356.221	214.801

TABLE 14 (Continued).—DRY MATTER AND ORGANIC MATTER IN FEED BY 30-DAY PERIODS

Period	Dry matter in grain *Pounds*	Dry matter in hay *Pounds*	Organic matter in grain *Pounds*	Organic matter in hay *Pounds*	Total organic matter *Pounds*	Digestible organic matter *Pounds*
Steer 528						
1	....	2.292	....	2.187	2.187	1.275
2	13.199	12.836	12.735	12.247	24.982	17.377
3	24.449	48.210	18.829	43.620	62.449	43.440
4	61.320	70.133	58.791	63.410	122.201	85.003
5	97.749	94.913	93.861	85.814	179.675	124.982
6	105.963	110.548	101.839	100.052	201.891	140.435
7	92.871	109.557	89.255	99.249	188.504	131.123
8	106.422	108.884	102.297	98.804	201.101	139.886
9	108.485	108.485	104.436	104.436	208.872	145.291
10	108.311	107.972	104.411	97.977	202.388	140.781
11	108.311	108.884	104.411	98.804	203.215	141.356
12	108.311	108.884	104.411	98.804	203.215	141.356
13	108.311	108.884	104.411	98.804	203.215	141.356
14	108.322	120.711	104.430	109.791	214.221	149.012
15	108.374	138.046	104.467	125.436	229.903	159.921
16	131.778	141.910	126.964	130.344	257.308	178.983
17	135.684	167.303	130.728	153.883	284.611	197.975
18	136.606	167.253	131.736	151.213	282.949	196.819
19	140.308	171.440	135.309	155.000	290.309	210.939
20	147.715	181.653	142.492	164.154	306.646	213.303
21	147.658	179.823	142.496	162.244	304.740	211.977
22	147.658	178.459	142.496	161.099	303.595	211.181
23	147.668	178.459	142.194	161.099	303.293	210.971
24	148.916	178.865	143.094	161.545	304.639	211.907
25	148.916	178.865	143.094	161.545	304.639	211.907
26	148.916	179.161	143.094	163.418	306.512	213.210
27	148.916	166.170	143.094	152.310	295.404	205.483
28	148.916	166.638	143.094	152.738	295.832	205.781
29	162.008	174.495	155.674	159.945	315.619	219.545
30	160.901	186.971	154.469	171.381	325.840	226.654
31	159.286	294.778	152.773	178.528	331.301	230.459
32	159.286	197.634	152.773	179.975	332.748	231.459
33	159.286	207.974	152.773	188.794	341.567	237.594
34	159.286	207.059	152.773	187.969	340.742	237.020
35	159.286	207.547	152.773	188.407	340.180	236.629
36	159.615	207.059	153.136	187.969	341.105	237.273
37	169.556	210.292	162.924	190.892	353.816	246.114
38	160.889	207.059	154.652	187.969	342.621	238.327
39	160.889	207.059	154.652	187.969	342.621	238.327
40	168.125	208.878	161.610	189.218	351.228	244.314
41	175.158	219.033	168.366	198.833	367.199	255.424
42	186.821	215.766	179.570	196.467	376.037	261.571
43	200.193	225.637	192.791	205.717	398.508	277.202
44	200.504	221.956	192.914	201.706	394.620	274.498
45	200.504	219.940	192.914	199.900	392.814	273.241
46	200.504	219.940	192.914	199.900	392.814	273.241
47	200.504	219.940	192.914	199.900	392.814	273.241
48	201.409	221.858	193.821	200.028	393.849	273.961
49	132.998	270.416	129.924	145.763	375.687	241.717
50	87.287	290.807	84.007	263.791	347.798	223.773
51	25.168	305.412	24.211	270.932	295.143	177.971
52	27.026	305.412	26.539	270.932	297.471	179.375

TABLE 14 (Continued).—DRY MATTER AND ORGANIC MATTER IN FEED BY 30-DAY PERIODS

Period	Dry matter in grain *Pounds*	Dry matter in hay *Pounds*	Organic matter in grain *Pounds*	Organic matter in hay *Pounds*	Total organic matter *Pounds*	Digestible organic matter *Pounds*
Steer 528 (Cont.)						
53	27.085	306.048	26.042	271.986	298.028	179.711
54	27.085	311.443	26.042	276.843	302.885	182.640
55	78.548	307.178	75.522	272.820	348.342	220.848
56	107.548	311.360	103.381	274.210	377.591	239.393
57	105.910	314.960	101.791	277.380	378.171	240.394
58	105.576	317.150	101.468	279.310	380.778	241.413
59	132.253	317.150	127.092	279.310	406.392	261.472
60	131.819	317.150	126.665	297.310	405.975	261.204
61	131.006	319.497	126.089	283.017	409.106	263.219
62	130.710	321.207	125.894	287.909	413.803	266.241
63	131.769	316.860	126.888	284.760	411.648	264.854
64	132.111	319.520	127.268	287.150	414.418	266.637
65	132.181	319.520	127.392	287.150	414.542	266.716
66	132.181	319.520	127.392	287.150	414.542	266.716
67	132.181	320.062	127.392	289.899	417.291	268.485
68	132.249	320.273	126.891	290.783	417.670	268.731
69	133.678	320.273	128.232	290.783	419.015	269.594
70	133.678	320.273	128.232	290.783	419.015	269.594
71	133.678	320.273	128.232	290.783	419.015	269.594
72	122.678	320.273	128.232	290.783	419.015	269.594
73	136.974	320.027	131.291	290.783	422.074	271.562
74	136.573	320.027	130.850	290.783	421.633	271.279
75	138.888	320.027	130.850	290.783	421.633	271.279
76	138.888	320.061	130.850	290.246	421.096	270.933
77	136.110	327.113	130.407	295.730	426.137	274.177
78	133.085	338.093	125.734	305.928	431.662	277.731
Steer 578						
1	22.361	104.971	21.945	96.528	118.023	74.827
2	39.593	102.156	38.058	92.737	130.795	82.924
3	64.522	124.266	62.020	111.347	173.367	111.544
4	80.281	131.978	77.222	120.328	197.550	127.104
5	67.831	180.588	65.270	164.178	229.448	147.627
6	72.191	150.751	69.459	137.011	206.470	132.843
7	112.607	151.207	109.855	137.427	247.232	159.101
8	25.852	151.207	24.874	137.427	162.301	102.899
9	19.304	152.693	18.577	137.668	156.245	94.216
10	8.998	176.927	8.660	160.696	169.356	98.768
11	....	180.748	....	161.434	161.434	94.148
12	....	180.485	....	160.100	160.100	93.370
13	....	180.485	....	160.100	160.100	93.370
14	....	192.763	....	171.302	171.302	99.903
15	....	194.679	....	173.056	173.056	100.926
16	1.805	159.232	1.736	144.700	146.436	85.400
17	....	204.744	....	180.211	180.211	105.099
18	....	199.535	....	175.740	175.740	102.492
19	....	211.430	....	186.214	186.214	108.600
20	....	211.430	....	186.214	186.214	108.600
21	....	211.430	....	186.214	186.214	108.600
22	....	212.996	....	188.682	188.682	110.039
23	....	215.343	....	193.013	193.013	112.565
24	....	217.377	....	195.347	195.347	113.926

TABLE 14 (Continued).—DRY MATTER AND ORGANIC MATTER IN FEED BY 30-DAY PERIODS

Period	Dry matter in grain *Pounds*	Dry matter in hay *Pounds*	Organic matter in grain *Pounds*	Organic matter in hay *Pounds*	Total organic matter *Pounds*	Digestible organic matter *Pounds*
Steer 578 (Cont.)						
25	14.981	238.663	14.438	214.483	228.921	133.507
26	26.438	239.560	25.480	215.280	240.760	145.178
27	26.879	239.560	25.905	215.280	241.185	145.435
28	26.438	216.989	25.480	194.367	219.847	132.568
29	26.718	240.187	25.633	218.066	243.699	146.950
30	26.727	240.187	25.638	218.066	243.704	146.954
31	26.727	240.187	25.638	218.066	243.704	146.954
32	26.727	240.187	25.638	218.066	243.704	146.954
33	26.727	240.187	25.638	218.066	243.704	146.954
34	27.065	240.187	26.652	218.006	244.718	147.565
35	27.778	240.187	26.614	218.066	244.680	147.542
36	27.778	240.187	26.614	218.066	244.680	147.542
37	27.778	244.278	26.614	221.518	248.132	149.624
38	27.778	253.795	26.614	229.446	256.060	154.404
39	26.616	253.795	25.147	229.446	254.593	153.520
Steer 577						
1	18.999	73.079	18.185	66.338	84.523	53.588
2	29.488	94.806	28.344	85.969	114.313	72.474
3	63.460	110.490	61.000	100.619	161.619	108.204
4	84.664	121.482	81.436	120.317	201.750	135.072
5	93.583	180.626	90.041	163.214	253.255	169.554
6	93.583	150.736	90.041	136.996	237.037	158.696
7	95.834	151.206	92.208	137.426	229.634	153.740
8	106.958	151.206	102.910	137.426	240.336	160.905
9	107.214	152.228	103.176	137.248	240.424	160.964
10	82.340	179.679	79.245	163.279	242.524	156.040
11	80.991	181.545	77.947	164.658	242.605	156.092
12	80.889	194.372	77.812	172.419	250.231	160.999
13	81.809	194.372	78.276	172.419	250.695	161.297
14	81.260	206.674	78.130	183.643	261.773	168.425
15	81.260	208.596	78.130	185.426	263.556	169.572
16	102.026	224.104	98.096	202.282	300.378	193.263
17	107.569	185.009	103.402	162.939	266.341	171.364
18	105.926	185.009	101.801	162.939	264.740	170.334
19	105.602	203.512	101.493	179.233	280.726	180.619
20	105.460	211.451	101.337	186.221	287.558	185.015
21	105.460	211.451	101.337	186.221	287.558	185.015
22	103.973	202.745	100.071	179.586	279.657	179.931
23	104.567	211.007	100.714	191.817	292.531	188.214
24	106.204	212.964	102.268	191.384	293.652	188.936
25	101.308	212.964	97.469	191.384	288.853	185.848
26	105.765	212.174	101.933	190.584	292.517	188.205
27	94.751	200.989	91.317	180.629	271.946	174.970
28	105.765	229.396	101.933	207.780	309.713	199.269
29	106.849	240.173	102.528	218.043	320.571	206.255
30	106.917	240.173	102.560	218.043	320.603	206.276
31	106.917	240.173	102.560	218.043	320.603	206.276
32	106.917	240.173	102.560	218.043	320.603	206.276
33	106.917	240.173	102.560	218.043	320.603	206.276
34	110.112	240.173	105.556	218.043	323.599	208.204
35	111.110	240.173	106.454	218.043	324.497	208.781

TABLE 14 (Continued).—DRY MATTER AND ORGANIC MATTER IN FEED BY 30-DAY PERIODS

Period	Dry matter in grain *Pounds*	Dry matter in hay *Pounds*	Organic matter in grain *Pounds*	Organic matter in hay *Pounds*	Total organic matter *Pounds*	Digestible organic matter *Pounds*
Steer 577 (Cont.)						
36	111.110	240.173	106.454	218.043	324.497	208.781
37	111.110	244.278	106.454	221.518	327.972	211.017
38	111.110	253.795	106.454	229.445	335.900	216.118
39	106.465	253.795	100.597	229.464	330.051	212.355
Steer 575						
1	12.158	69.762	11.512	63.329	74.841	46.618
2	.182	69.026	.175	62.661	62.836	36.646
3	....	115.261	....	106.173	106.173	61.920
4	15.236	151.560	14.659	140.360	155.019	90.407
5	26.742	142.210	26.730	129.225	154.955	90.370
6	26.742	150.379	26.730	136.669	162.399	94.711
7	16.314	151.206	15.696	137.426	153.122	89.008
8	....	142.028	....	129.078	129.078	75.278
9	....	147.389	....	133.779	133.779	78.020
10	....	139.213	....	125.591	125.591	73.245
11	....	137.162	....	124.453	124.453	72.581
12	....	138.828	....	123.158	123 158	71.826
13	....	138.828	....	123.158	123.158	71.826
14	....	149.691	....	133.024	133.024	77.580
15	....	152.834	....	136.004	136.044	79.318
16	24.831	140.477	23.875	124.735	148.610	94.219
17	47.748	178.010	45.892	162.140	208.032	131.892
18	52.087	130.398	50.059	114.848	164.907	104.551
19	52.798	136.154	50.744	120.404	171.148	108.508
20	52.728	136.154	50.668	120.404	171.072	108.460
21	52.728	136.154	50.668	120.404	171.072	108.460
22	52.419	133.109	50.452	117.913	168.365	106.743
23	52.284	137.308	50.357	123.075	173.432	109.956
24	53.047	158.877	51.084	142.777	193.861	122.908
25	52.848	159.736	50.911	143.556	194.467	123.292
26	52.877	159.736	50.961	143.556	194.517	123.324
27	52.877	159.736	50.961	143.556	194.517	123.324
28	52.887	149.840	50.961	144.933	195.894	124.197
29	21.274	160.112	19.105	145.362	164.467	104.272
30	53.460	160.552	51.281	145.762	197.043	124.925
31	53.460	160.552	51.281	145.762	197.043	124.925
32	53.460	160.552	51.281	145.762	197.043	124.925
33	53.460	160.552	51.281	145.762	197.043	124.925
34	54.556	160.552	52.578	145.762	198.340	125.748
35	55.555	160.552	53.227	145.762	198.989	126.159
36	55.555	160.552	53.227	145.762	198.989	126.159
37	55.555	162.844	53.227	147.764	200.991	127.428
38	55.555	169.196	53.227	152.964	206.191	130.725
39	53.233	169.196	50.293	152.964	203.257	128.845
Steer 574						
1	16.086	72.337	15.462	65.667	81.129	51.436
2	8.758	82.829	8.419	75.192	83.611	50.417
3	20.911	118.144	20.100	107.764	127.864	81.066
4	54.842	132.642	53.328	120.860	174.188	110.435
5	41.451	139.717	39.882	127.064	166.946	105.844

TABLE 14 (Continued).—DRY MATTER AND ORGANIC MATTER IN FEED BY 30-DAY PERIODS

Period	Dry matter in grain *Pounds*	Dry matter in hay *Pounds*	Organic matter in grain *Pounds*	Organic matter in hay *Pounds*	Total organic matter *Pounds*	Digestible organic matter *Pounds*
Steer 574 (Cont.)						
6	45.109	150.755	43.389	137.013	180.402	114.375
7	45.686	151.215	43.959	137.431	181.390	115.001
8	10.198	151.215	9.810	137.431	147.241	88.786
9	4.942	152.268	4.762	137.288	142.050	82.844
10	....	160.321	....	145.659	145.659	84.948
11	....	159.116	....	144.338	144.338	84.178
12	....	166.605	....	147.795	147.795	86.194
13	....	166.605	....	147.795	147.795	86.194
14	....	169.588	....	150.701	150.701	87.889
15	....	180.783	....	160.703	160.703	93.722
16	....	262.436	....	240.717	240.717	140.386
17	29.015	169.589	27.887	149.359	177.246	110.407
18	52.969	154.553	50.906	136.166	187.072	118.604
19	52.799	158.582	50.736	139.662	190.398	120.712
20	52.730	158.582	50.668	139.662	190.330	120.669
21	52.730	158.582	50.668	139.662	190.330	120.669
22	52.823	162.733	50.856	144.498	195.354	123.954
23	52.284	160.518	50.357	143.869	194.226	123.139
24	53.047	159.736	51.081	143.556	194.637	123.400
25	52.850	159.736	50.913	143.556	194.469	123.293
26	52.877	159.736	50.961	143.556	194.517	123.324
27	52.877	159.736	50.961	143.556	194.517	123.324
28	52.877	185.616	50.961	170.530	221.491	140.425
29	53.402	160.127	51.250	145.377	196.627	124.662
30	53.460	160.571	51.281	145.781	197.062	124.937
31	53.460	160.571	51.281	145.781	197.062	124.937
32	53.460	160.571	51.281	145.781	197.062	124.937
33	53.460	160.571	51.281	145.781	197.062	124.937
34	54.556	160.571	52.578	145.781	198.359	125.760
35	55.556	160.571	52.578	145.781	199.008	126.171
36	55.555	160.571	53.227	145.781	199.008	126.171
37	55.555	162.844	53.227	147.764	200.991	127.428
38	55.555	169.196	53.227	152.964	206.191	130.725
39	53.233	169.196	50.293	152.964	203.257	128.865
Steer 573						
1	12.605	59.714	12.117	54.205	66.322	42.048
2	34.491	94.115	29.300	85.441	114.741	72.746
3	67.653	101.288	65.030	92.233	157.263	105.288
4	94.395	120.418	90.791	109.788	200.579	139.523
5	77.992	134.305	75.042	122.030	197.072	131.940
6	65.162	138.195	62.733	136.822	199.555	128.394
7	55.708	151.216	53.600	137.436	191.036	123.913
8	26.740	151.216	25.728	137.436	163.164	103.446
9	26.458	152.228	25.462	137.248	162.710	103.158
10	13.499	193.531	12.992	177.521	190.513	114.879
11	5.399	185.064	5.196	168.046	173.242	101.035
12	....	194.340	....	172.390	172.390	100.538
13	....	194.340	....	172.390	172.390	100.538
14	....	206.712	....	183.652	183.652	107.106
15	....	208.516	....	185.426	185.426	108.140
16	....	196.976	....	174.949	174.949	102.030

TABLE 14 (Continued).—DRY MATTER AND ORGANIC MATTER IN FEED BY 30-DAY PERIODS

Period	Dry matter in grain *Pounds*	Dry matter in hay *Pounds*	Organic matter in grain *Pounds*	Organic matter in hay *Pounds*	Total organic matter *Pounds*	Digestible organic matter *Pounds*
Steer 573 (Cont.)						
17	8.437	147.573	8.108	129.973	137.081	82.660
18	26.485	159.023	25.453	140.053	165.506	103.094
19	26.401	195.150	25.374	171.870	197.244	122.863
20	26.365	195.150	25.334	171.870	197.204	122.839
21	36.957	187.201	35.479	164.871	200.350	127.022
22	52.070	186.347	50.103	165.079	215.182	136.425
23	52.285	189.491	50.358	169.844	220.202	139.608
24	53.046	193.005	51.081	173.465	224.536	142.356
25	52.849	185.425	50.912	166.635	217.547	137.925
26	52.877	186.335	50.961	167.455	218.416	138.476
27	52.877	182.819	50.961	164.299	215.260	136.475
28	52.877	178.251	50.961	161.515	212.476	134.710
29	53.447	186.960	51.277	169.782	221.019	140.126
30	53.460	170.905	51.281	169.188	220.469	139.777
31	53.460	171.309	51.281	169.588	220.869	140.031
32	53.460	171.309	51.281	169.588	220.869	140.031
33	53.460	171.309	51.281	169.588	220.869	140.031
34	54.556	171.309	52.578	169.588	222.166	140.853
35	55.555	171.309	53.227	169.588	222.815	141.265
36	55.555	171.309	53.227	169.588	222.815	141.265
37	55.555	189.994	53.227	172.293	225.520	142.980
38	55.555	197.396	53.227	178.458	231.785	146.952
39	53.233	197.396	50.293	178.458	228.751	145.028
Steer 572						
1	14.652	66.795	14.084	60.635	74.719	47.372
2	19.763	48.768	18.997	76.952	95.949	60.832
3	25.738	116.754	24.740	106.329	131.069	83.098
4	26.760	116.404	25.741	115.288	141.029	89.412
5	26.731	135.427	25.729	123.064	148.793	94.335
6	26.741	164.213	25.729	151.683	177.412	112.479
7	14.535	141.583	13.985	128.630	142.665	86.027
8	....	103.436	....	90.486	90.486	52.771
9	.445	138.389	.428	124.779	125.207	73.020
10	....	138.416	....	125.794	125.794	73.363
11	....	137.202	....	124.236	124.236	72.454
12	....	138.838	....	123.158	123.158	71.826
13	....	138.838	....	123.158	123.158	71.826
14	....	152.948	....	135.909	135.909	79.262
15	....	152.973	....	135.983	135.983	79.305
16	....	165.518	....	147.204	147.204	85.849
17	....	165.933	....	146.688	146.688	85.546
18	....	163.897	....	145.077	145.077	84.609
19	....	170.337	....	150.687	150.687	87.880
20	....	191.319	....	169.249	169.249	98.706
21	....	191.319	....	169.249	169.249	98.706
22	....	188.313	....	167.389	167.389	97.621
23	....	189.891	....	164.650	164.650	96.024
24	....	186.759	....	167.839	167.839	97.884
25	....	186.314	....	167.455	167.455	97.660
26	....	186.333	....	167.455	167.455	97.660
27	....	186.333	....	167.455	167.455	97.660

TABLE 14 (Continued).—DRY MATTER AND ORGANIC MATTER IN FEED BY 30-DAY PERIODS

Period	Dry matter in grain *Pounsd*	Dry matter in hay *Pounds*	Organic matter in grain *Pounds*	Organic matter in hay *Pounds*	Total organic matter *Pounds*	Digestible organic matter *Pounds*
Steer 572 (Cont.)						
28	....	177.007	....	161.031	161.031	93.913
29	....	199.681	....	181.281	181.281	105.723
30	....	214.805	....	195.015	195.015	113.733
31	....	225.909	....	205.099	205.099	119.614
32	....	240.613	....	218.433	218.433	127.390
33	....	240.613	....	218.433	218.433	127.399
34	....	212.135	....	192.595	192.595	112.321
35	....	240.613	....	218.433	218.433	127.390
36	....	240.613	....	218.433	218.433	127.390
37	....	244.276	....	221.518	221.518	129.199
38	....	253.795	....	229.446	229.446	133.813
39	....	253.795	....	229.446	229.446	133.813
Steer 571						
1	21.901	72.984	21.025	56.247	87.272	55.292
2	29.045	94.772	27.918	86.032	113.950	72.244
3	72.497	96.069	69.688	87.970	157.658	109.666
4	97.728	104.381	94.004	95.171	139.175	96.801
5	94.529	127.521	90.957	117.834	208.791	145.235
6	90.913	123.562	87.472	112.292	199.764	138.955
7	90.913	125.082	87.472	113.682	201.154	139.922
8	90.913	127.725	87.472	112.445	199.917	139.062
9	127.496	95.030	122.696	85.680	108.376	144.946
10	68.385	163.855	65.815	148.935	214.750	136.152
11	62.991	172.918	60.624	156.704	217.328	137.786
12	67.402	180.741	64.838	160.371	225.209	142.783
13	86.448	180.741	83.134	160.371	243.505	154.382
14	67.705	193.738	65.097	172.265	237.362	150.488
15	67.705	194.670	65.097	173.040	238.157	150.979
16	79.906	193.852	76.829	172.117	248.946	160.171
17	80.680	143.604	77.554	126.474	204.028	131.271
18	79.688	159.023	76.581	140.053	216.634	139.382
19	79.204	182.380	76.122	160.620	236.742	152.319
20	79.095	185.009	76.003	162.939	238.942	153.735
21	78.346	185.009	75.236	162.939	238.175	153.241
22	78.263	183.664	67.282	165.090	232.372	149.508
23	78.425	187.272	75.535	167.851	243.386	156.595
24	78.236	183.263	75.394	164.693	240.087	154.472
25	79.228	186.335	76.287	167.455	243.742	156.824
26	79.235	186.335	76.364	167.455	243.819	156.873
27	79.316	189.013	76.442	169.863	246.305	158.473
28	79.316	204.484	76.442	185.209	261.651	168.346
29	80.160	215.246	76.905	195.416	272.321	172.651
30	80.188	213.455	76.920	193.795	270.615	171.633
31	78.852	208.103	75.639	184.533	260.172	164.949
32	80.188	208.103	76.920	184.533	261.453	165.761
33	80.188	208.103	76.920	184.544	261.464	165.768
34	82.282	208.103	78.865	184.544	263.409	167.001
35	83.333	208.103	79.841	184.544	264.385	167.620
36	83.333	208.103	79.841	184.544	264.385	167.620
37	83.333	217.133	79.841	196.902	276.743	175.455
38	83.333	225.595	79.841	203.952	283.793	179.925
39	79.850	225.595	77.434	203.952	281.386	177.399

TABLE 15.—MEASUREMENTS IN CENTIMETERS OF STEERS AT BEGINNING OF SUMMER PERIODS AND END OF WINTER PERIODS

STEER 585

Date	5-22-14	4-17-15	4-12-16	4-7-17	5-2-18	4-27-19	4-21-20
Height at withers	79.5	91.0	103.5	114.5	121.5	124.0	128.0
Height at hips	83.5	93.0	107.0	117.0	126.5	128.0	130.0
Girth of throat	47.0	52.0	64.0	72.0	79.0	78.0	85.0
Depth of chest	32.5	41.0	49.5	55.0	60.0	61.0	62.5
Width of chest	18.0	21.0	23.0	25.0	26.0	29.0	30.0
Width of paunch	20.4	31.0	38.0	42.0	45.5	52.5	54.5
Foreleg elbow to ground	49.0	53.0	63.0	65.0	72.0	72.0	74.0
Point of shoulder to top hip point	60.0	68.0	87.0	94.0	96.0	101.5	109.0
Point of shoulder to ground	60.0	63.0	73.0	77.0	81.5	85.0	92.0
Poll to point of muzzle	26.0	31.0	39.0	44.0	49.0	49.0	49.0
Heart girth	85.0	102.0	121.0	140.0	149.0	153.0	163.0
Paunch girth	85.0	124.0	139.0	157.0	162.0	183.0	192.0
Width of hips	20.0	27.0	34.0	39.0	42.5	43.0	46.0
Width of loin	14.0	18.5	21.5	24.5	25.0	32.5	31.5

STEER 528

Date	6-11-14	4-17-15	4-12-16	4-7-17	5-2-18	4-27-19	4-21-20
Height at withers	81.8	109.0	122.5	130.0	138.5	140.0	143.0
Height at hips	86.3	110.5	126.5	136.0	141.0	143.0	144.5
Girth of throat	54.0	75.0	83.0	94.0	100.0	96.0	100.0
Depth of chest	36.5	53.0	61.5	66.0	73.0	76.0	78.0
Width of chest	20.3	30.0	33.5	40.0	41.0	41.0	43.5
Width of paunch	25.0	41.0	46.0	59.0	61.0	61.0	64.0
Foreleg elbow to ground	50.5	62.0	70.0	75.0	77.0	79.5	80.0
Point of shoulder to top hip point	64.0	87.0	103.0	112.0	114.0	122.0	125.0
Point of shoulder to ground	60.5	72.0	82.0	86.0	91.0	92.0	96.0
Poll to point of muzzle	27.5	38.0	45.0	54.0	56.0	57.0	58.0
Heart girth	95.0	136.0	157.0	175.0	191.0	194.5	201.0
Paunch girth	98.0	144.0	166.0	193.0	206.0	209.0	217.0
Width of hips	22.7	35.0	42.5	49.5	54.5	56.0	59.0
Width of loin	15.3	24.0	27.0	31.5	35.0	38.5	36.0

STEER 579

Date	5-30-14	4-17-15	4-12-16	4-7-17	5-2-18	4-27-19	4-21-20
Height at withers	81.5	104.0	114.5	126.0	135.5	137.5	139.0
Height at hips	75.4	105.0	117.0	128.5	136.5	137.5	140.0
Girth of throat	49.0	64.0	69.0	73.0	83.0	79.0	85.0
Depth of chest	34.5	47.0	54.5	59.5	66.0	67.5	69.0
Width of chest	18.5	23.0	25.5	29.0	32.0	31.5	36.0
Width of paunch	23.0	32.0	40.0	46.0	53.0	49.5	52.0
Foreleg elbow to ground	51.0	63.0	68.0	75.0	79.0	83.0	84.0
Point of shoulder to top hip point	62.0	84.0	99.0	105.0	114.0	121.0	121.0
Point of shoulder to ground	57.0	68.0	78.0	85.0	88.0	92.0	95.0
Poll to point of muzzle	27.5	36.0	43.0	49.0	53.0	52.5	53.0
Heart girth	90.0	120.0	137.0	150.0	168.0	169.0	171.0
Paunch girth	92.0	129.0	142.0	162.0	181.0	181.0	187.0
Width of hips	21.5	30.0	36.0	41.0	47.0	47.0	49.0
Width of loin	14.9	21.0	20.0	23.5	27.0	31.5	31.5

Table 15 (Continued).—Measurements in Centimeters of Steers at Beginning of Summer Periods and End of Winter Periods

	STEER 578			STEER 577			STEER 575
Date	5-2-18	4-27-19	4-21-20	5-2-18	4-27-19	4-21-20	5-2-18
Height at withers	107.0	113.0	118.5	113.5	127.0	134.0	100.0
Height at hips	110.0	114.0	120.5	116.75	130.0	136.5	101.5
Girth of throat	64.0	63.0	75.0	73.0	79.0	90.0	60.0
Depth of chest	51.0	53.5	57.5	56.0	64.5	71.5	46.5
Width of chest	24.0	25.0	27.5	28.0	32.5	37.0	21.0
Width of paunch	39.5	46.0	55.0	40.0	52.0	55.0	36.5
Foreleg elbow to ground	64.5	67.0	69.0	70.0	76.5	79.0	60.0
Point of shoulder to top hip point	86.0	91.5	97.0	89.0	106.0	109.0	78.0
Point of shoulder to ground	72.0	76.5	82.0	78.0	88.0	95.0	69.0
Poll to point of muzzle	40.0	42.0	44.0	43.5	50.0	53.0	38.5
Heart girth	128.0	132.0	145.0	141.0	165.0	180.0	119.0
Paunch girth	146.0	162.0	183.0	149.0	179.0	197.0	131.0
Width of hips	34.0	35.5	41.0	34.5	41.5	46.5	27.5
Width of loin	19.0	24.0	26.0	23.5	31.0	35.0	18.0

	STEER 575 (Cont.)		STEER 574			STEER 573	
Date	4-27-19	4-21-20	5-2-18	4-27-19	4-21-20	5-2-18	4-27-19
Height at withers	106.5	114.0	99.0	104.0	111.0	102.0	109.0
Height at hips	109.0	116.5	103.0	107.0	114.5	102.5	109.5
Girth of throat	63.0	63.0	63.0	65.5	72.0	66.0	68.0
Depth of chest	52.0	55.0	49.0	52.5	57.5	52.5	56.5
Width of chest	25.0	27.5	23.5	26.0	25.5	26.0	27.0
Width of paunch	43.0	44.5	37.0	42.0	42.5	39.0	44.5
Foreleg elbow to ground	64.0	70.0	59.0	64.0	68.0	58.0	63.0
Point of shoulder to top hip point	87.0	94.0	80.0	87.0	96.0	77.0	87.0
Point of shoulder to ground	72.0	79.0	66.5	71.0	76.0	68.0	71.0
Poll to point of muzzle	42.0	47.0	39.0	42.5	46.0	40.0	43.0
Heart girth	130.0	142.0	127.0	132.0	145.0	131.0	137.0
Paunch girth	148.0	159.0	135.0	144.0	154.0	141.0	153.0
Width of hips	31.0	36.0	30.0	33.0	36.0	31.0	33.5
Width of loin	22.0	23.0	21.0	22.0	23.0	20.0	25.0

	STEER 573 (Cont.)	STEER 572			STEER 571		
Date	4-21-20	5-2-18	4-27-19	4 21-20	5-2-18	4-27-19	4-21-20
Height at withers	117.0	98.5	105.0	107.5	100.25	114.5	118.5
Height at hips	115.5	99.25	105.4	110.5	104.75	117.5	123.0
Girth of throat	74.0	60.0	62.0	67.0	65.0	75.5	80.0
Depth of chest	61.0	46.0	48.5	51.0	51.0	57.5	62.5
Width of chest	28.5	23.0	24.0	26.0	26.5	31.5	33.0
Width of paunch	47.0	33.5	40.0	47.0	40.0	47.5	50.0
Foreleg elbow to ground	70.0	61.0	62.0	69.0	60.5	69.0	73.0
Point of shoulder to top hip point	90.0	76.0	83.5	89.0	81.0	98.0	101.0
Point of shoulder to ground	77.0	69.0	71.5	76.5	67.5	77.5	81.0
Poll to point of muzzle	46.0	39.0	41.5	44.0	39.0	47.0	49.0
Heart girth	155.0	116.0	124.0	133.0	131.0	149.0	160.0
Paunch girth	166.0	124.0	136.0	158.0	143.0	162.5	175.0
Width of hips	37.0	29.25	31.0	34.0	31.5	38.0	41.0
Width of loin	27.5	18.25	19.5	27.0	19.75	23.0	28.0

TABLE 16.—MEASUREMENTS IN CENTIMETERS OF STEERS AT END OF SUMMER PERIODS AND BEGINNING OF WINTER PERIODS

STEER 585

Date	10-19-14	10-13-15	10-8-16	10-3-17	10-28-18	10-23-19	10-17-20
Height at withers	87.5	94.7	109.0	118.5	122.0	125.0	129.5
Height at hips	92.0	100.0	114.0	122.0	126.0	127.5	130.5
Girth of throat	52.0	53.0	64.0	70.0	73.0	79.0	81.0
Depth of chest	39.5	42.0	50.0	55.0	59.0	61.0	65.5
Width of chest	19.0	19.0	23.0	25.0	25.0	29.5	36.0
Width of paunch	29.5	33.5	40.0	43.5	44.0	52.0	61.0
Foreleg, elbow to ground	52.0	59.0	65.0	69.0	73.0	74.0	74.0
Point of shoulder to top hip point	68.5	73.0	91.0	91.0	99.0	102.0	114.0
Point of shoulder to ground	64.0	64.0	75.0	81.0	82.0	85.5	89.0
Poll to point of muzzle	32.0	33.0	43.0	46.5	48.0	48.5	51.0
Heart girth	99.0	107.0	123.0	139.0	145.0	154.0	169.0
Paunch girth	116.0	129.0	145.0	160.0	166.0	185.0	204.0
Width of hips	26.5	29.7	36.0	38.0	41.0	43.5	47.5
Width of loin	17.0	18.0	20.0	24.0	26.0	30.0	36.0

STEER 528

Date	10-19-14	10-13-15	10-8-16	10-3-17	10-28-18	10-29-19	10-17-20
Height at withers	101.5	115.5	127.0	133.5	139.0	144.0	144.0
Height at hips	103.5	120.5	131.5	138.5	143.0	144.5	143.0
Girth of throat	68.0	73.0	83.0	93.	95.0	99.0	102.0
Depth of chest	46.5	55.5	64.5	71.0	73.5	78.0	79.0
Width of chest	26.0	28.0	35.5	38.5	38.0	41.0	46.0
Width of paunch	39.5	46.7	52.5	55.5	55.0	62.5	65.0
Foreleg, elbow to ground	60.0	70.0	72.0	76.0	81.0	81.5	77.0
Point of shoulder to top hip point	80.0	95.0	104.0	113.0	122.0	124.5	120.0
Point of shoulder to ground	67.0	77.0	87.0	88.0	89.0	94.0	96.0
Poll to point of muzzle	35.0	40.0	50.0	55.5	55.0	57.0	58.0
Heart girth	125.0	144.0	165.0	180.0	189.0	198.5	205.0
Paunch girth	144.0	164.0	183.0	192.0	198.0	214.0	222.0
Width of hips	32.0	39.2	46.5	51.0	54.5	59.0	60.0
Width of loin	20.5	23.0	30.0	31.0	34.5	36.5	39.5

STEER 579

Date	10-19-14	10-13-15	10-8-16	10-3-17	10-28-18	10-29-19	10-17-20
Height at withers	96.0	110.0	121.0	129.5	135.5	138.5	139.5
Height at hips	101.5	114.0	125.0	133.5	137.0	138.5	141.0
Girth of throat	59.0	62.0	69.0	80.0	77.0	78.0	81.5
Depth of chest	42.0	49.5	55.0	61.5	64.0	65.5	68.5
Width of chest	21.0	24.0	29.0	30.5	29.5	31.5	39.0
Width of paunch	31.5	39.0	43.5	45.5	48.0	47.5	52.0
Foreleg, elbow to ground	60.0	67.5	69.0	74.0	82.5	83.0	78.0
Point of shoulder to top hip point	79.0	91.0	100.0	112.0	120.0	119.0	118.0
Point of shoulder to ground	65.0	75.0	85.0	85.0	90.0	90.5	94.5
Poll to point of muzzle	34.0	38.0	46.0	51.5	53.0	52.0	54.0
Heart girth	110.5	124.0	143.0	155.0	163.0	164.0	176.5
Paunch girth	124.0	143.0	155.0	167.0	172.0	176.0	191.0
Width of hips	28.0	32.7	39.0	43.5	47.0	48.0	50.0
Width of loin	20.0	20.5	22.0	25.0	26.5	30.5	31.5

TABLE 16 (Continued).—MEASUREMENTS IN CENTIMETERS OF STEERS AT END OF SUMMER PERIODS AND BEGINNING OF WINTER PERIODS

	STEER 578				STEER 577		
Date	11-3-17	10-28-18	10-29-19	10-17-20	11-3-17	10-28-18	10-29-19
Height at withers	97.0	110.5	113.5	121.0	97.0	122.0	132.0
Height at hips	100.0	111.5	117.0	123.0	102.0	124.5	135.0
Girth of throat	56.0	60.0	66.0	69.0	60.0	73.0	79.0
Depth of chest	43.0	50.5	53.5	59.0	45.0	59.0	67.0
Width of chest'	21.5	24.5	24.0	27.5	27.0	30.0	35.5
Width of paunch	40.5	43.0	49.5	51.0	39.0	46.0	52.5
Foreleg, elbow to ground	57.0	64.0	69.0	69.0	61.0	71.0	80.0
Point of shoulder to top hip, point	76.0	90.0	94.0	105.0	74.0	100.0	109.0
Point of shoulder to ground	67.0	75.0	81.0	82.0	68.0	81.0	89.5
Poll to point of muzzle	35.5	41.0	43.0	48.0	35.5	46.0	50.5
Heart girth	111.0	126.0	137.0	151.0	115.0	150.0	171.0
Paunch girth	138.0	154.0	171.0	177.0	137.0	166.0	186.0
Width of hips	29.0	34.0	37.5	41.0	27.5	38.0	44.0
Width of loin	17.5	20.5	24.0	26.5	18.5	25.0	33.0

	STEER 577—(Cont.)	STEER 575				STEER 574	
Date	10-17-20	11 3-17	10-28-18	10-29-19	10-17-20	11-3-17	10-28-18
Height at withers	136.5	91.5	102.5	111.0	118.5	91.0	102.0
Heiтht at hips	138.0	95.0	104.5	115.5	119.0	95.5	105.0
Girth of throat	89.0	55.0	57.0	70.0	72.0	58.5	57.0
Depth of chest	73.0	42.0	47.5	54.0	57.5	44.5	49.5
Width of chest	40.0	21.0	22.0	26.0	29.5	23.0	24.0
Width of paunch	56.0	36.0	42.5	47.5	49.5	39.0	40.0
Foreleg, elbow to ground	81.5	57.0	62.0	69.0	70.0	56.0	60.0
Point of shoulder to top hip point	122.0	72.0	85.0	91.5	100.0	72.0	83.0
Point of shoulder to ground	93.0	65.0	69.0	78.5	79.0	63.0	67.0
Poll to point of muzzle	56.0	34.0	40.0	45.0	50.0	36.0	41.0
Heart girth	181.0	107.0	119.0	137.0	146.0	113.0	128.0
Paunch girth	201.0	129.0	148.0	165.0	169.0	132.0	148.0
Width of hips	48.0	24.0	28.0	33.0	37.5	27.0	30.5
Width of loin	35.5	16.5	18.5	23.0	26.5	17.0	22.0

	STEER 574—(Cont.)		STEER 573				STEER 572
Date	10-29-19	10-17-20	11-3-17	10-28-18	10-29-19	10-17-20	11-3-17
Height at withers	108.5	114.0	92.0	106.5	114.5	119.0	89.5
Height at hips	112.0	116.5	94.0	107.0	115.0	118.5	93.0
Girth of throat	69.0	70.0	58.0	64.0	74.0	75.0	55.0
Depth of chest	56.0	60.5	44.5	51.5	58.0	68.0	40.5
Width of chest	29.0	32.5	24.5	25.0	30.0	30.5	22.5
Width of paunch	46.5	47.0	39.0	43.0	48.5	50.5	36.0
Foreleg, elbow to ground	66.0	65.0	55.0	62.0	68.0	66.5	56.0
Point of shoulder to top hip point	92.5	100.0	71.0	83.0	94.0	101.0	70.0
Point of shoulder to ground	75.0	78.0	63.0	72.0	75.5	79.0	62.0
Poll to point of muzzle	45.5	49.0	35.0	41.0	44.5	49.0	34.0
Heart girth	145.0	150.0	116.0	133.0	149.0	159.0	116.0
Paunch girth	160.0	165.0	138.0	150.0	167.0	175.0	126.0
Width of hips	35.0	38.0	28.0	31.5	36.0	39.0	25.0
Width of loin	25.0	27.5	19.0	21.0	28.0	27.5	16.5

TABLE 16 (Continued).—MEASUREMENTS IN CENTIMETERS OF STEERS AT END OF SUMMER PERIODS AND BEGINNING WINTER PERIODS

STEER 572—(Cont.)				STEER 571			
Date	10-28-18	10-29-19	10-17-20	11-3-17	10 28-18	10-29-19	10-17-20
Height at withers	102.25	107.5	115.5	83.5	107.0	116.0	120.0
Height at hips	102.25	109.0	113.0	88.5	111.0	120.5	123.5
Girth of throat	58.0	65.0	65.0	54.0	68.0	72.0	78.0
Depth of chest	46.5	50.0	54.5	39.0	53.0	59.5	63.5
Width of chest	23.5	24.0	29.0	20.0	29.0	33.5	34.5
Width of paunch	39.5	41.0	49.0	35.0	48.0	50.0	52.5
Foreleg, elbow to ground	63.0	67.0	67.0	53.0	66.0	71.5	72.0
Point of shoulder to top hip point	82.0	85.5	98.0	65.0	88.0	101.0	110.0
Point of shoulder to ground	67.0	76.0	77.0	57.0	70.0	81.5	80.0
Poll to point of muzzle	39.0	42.0	46.0	32.0	42.0	49.0	51.0
Heart girth	120.0	129.0	137.0	100.0	140.0	156.0	165.0
Paunch girth	138.0	145.0	163.0	125.0	163.0	167.0	182.0
Width of hips	30.0	32.0	35.0	24.0	35.0	39.5	43.0
Width of loin	18.5	23.0	26.5	16.0	23.0	29.0	28.5

TABLE 17.—MEASUREMENTS* IN CENTIMETERS OF CONTROL ANIMALS AT TIME OF SLAUGHTER

Steer No.	554	552	523	526	512	531	525	509
Height at withers	90.5	96.5	128.8	130.0	153.0	114.75	124.8	140.0
Height at hips	96.8	98.0	130.0	140.5	150.5	115.5	126.8	139.0
Girth of throat	55.0	60.0	87.0	94.0	100.0	72.0	80.0	90.5
Depth of chest	38.5	44.0	66.0	71.5	80.0	54.5	62.0	67.0
Width of chest	22.3	25.0	36.0	43.0	44.5	26.5	30.5	40.5
Width of Paunch	25.6	33.3	62.0	57.0	62.0	42.0	54.0	53.0
Foreleg, elbow to ground	60.0	61.2	76.5	85.0	88.0	72.5	73.8	84.5
Point of shoulder to top hip point	70.5	75.0	112.0	124.0	127.0	94.0	105.0	116.0
Point of shoulder to ground	67.0	70.0	88.0	94.0	101.0	88.5	85.0	98.5
Poll to point of muzzle	31.5	35.0	52.5	54.0	55.0	43.0	51.0	52.0
Heart girth	101.0	114.0	175.0	197.0	210.0	146.0	160.0	186.0
Paunch girth	103.0	125.0	210.0	212.0	220.0	160.0	189.0	204.0
Width of hips	23.1	27.0	46.0	53.0	56.0	35.5	40.5	48.5
Width of loin	17.0	21.7	37.0	41.0	43.5	27.5	31.5	41.0

*From unpublished data furnished by C. R. Moulton, department agricultural chemistry, Missouri Agricultural Experiment Station.

Table 18.—Composition of Control Animals

Steer	Age days	Weight pounds	Composition of body		
			Dry matter per cent	Protein per cent	Fat per cent
554	90	196.0	32.836	20.038	7.395
552	160	256.2	35.928	19.469	10.555
523	798	864.2	39.479	19.219	15.134
526	1217	1088.2	44.552	18.813	20.435
512	1454	1250.4	48.001	18.094	24.299
531	588	479.6	37.227	20.263	10.355
525	800	694.6	37.338	20.031	11.787
509	1363	1004.2	42.079	20.181	16.232

From unpublished data furnished by C. R. Moulton, department agricultural chemistry Missouri Agricultural Experiment Station.

Table 19.—Energy Value of Gains, Calculated for Summer Periods

Period† Steer	1 Therms	2 Therms	3 Therms	4 Therms	5 Therms	6 Therms	7 Therms
Group 1							
528	.95575	1.0918	1.2279	1.7136	2.1993	2.500	3.000
577	1.0918	1.2279	1.7136	....	....	....	....
571	1.0918	1.2279	1.7136	....	....	....	....
Group II							
579	.95575	1.0583	1.0583	1.1608	1.4104	1.5352	1.66
578	1.0583	1.0583	1.1608	....	....	....	....
573	1.0583	1.0583	1.1608	....	....	....	....
Group III							
585	.8343	.9445	.9445	1.0548	1.1013	1.1479	1.649
575	.9445	1.0548	1.1013	....	....	....	....
574	.9445	1.0548	1.1013	....	....	....	....
572	.9445	1.0548	1.1013	....	....	....	....

Table 18 shows the ages, weights, and percentage composition of live weight of the control animals used in this study.

†These same values apply also to the winter periods of the seven younger steers. In the case of the three older animals, Nos. 528, 579, and 585, the first winter period corresponds to the second summer period and so on, thus making the sixth winter period correspond to the seventh summer period.

From these data the composition of the gains was estimated for all periods except period seven of 528. No control animal to fit this period could be found. The value of three therms per pound gain was used in this case. This value was assumed on the basis of Armsby's calculation (3f) of the energy value of gains from Lawes and Gilbert's analyses on four-year-old fattening cattle.

Table 19 shows the estimated energy value of the gains by periods for all the steers.

Table 20 shows distribution of the control animals. Check animals were first fitted to the old steer in each group; then the young animals were compared with the old animal in their respective groups rather than with check animals direct.

TABLE 20.—DISTRIBUTION OF CONTROL ANIMALS.

Period	1	2	3	4	5	6	7
Steer 528	552	Interpolate	523	Interpolate	526	512	....
577 571	Period 2 of 528	523	Period 4 of 528	....	....	....	....
579	552	Interpolate	Interpolate	525	Interpolate	Interpolate	509
578 573	Period 2 of 579	Period 3 of 579	525	....	....	....	....
585	554	Interpolate	Interpolate	531	Interpolate	525	523 ....
575 574 572	Period 3 of 585	531	Period 5 of 585				

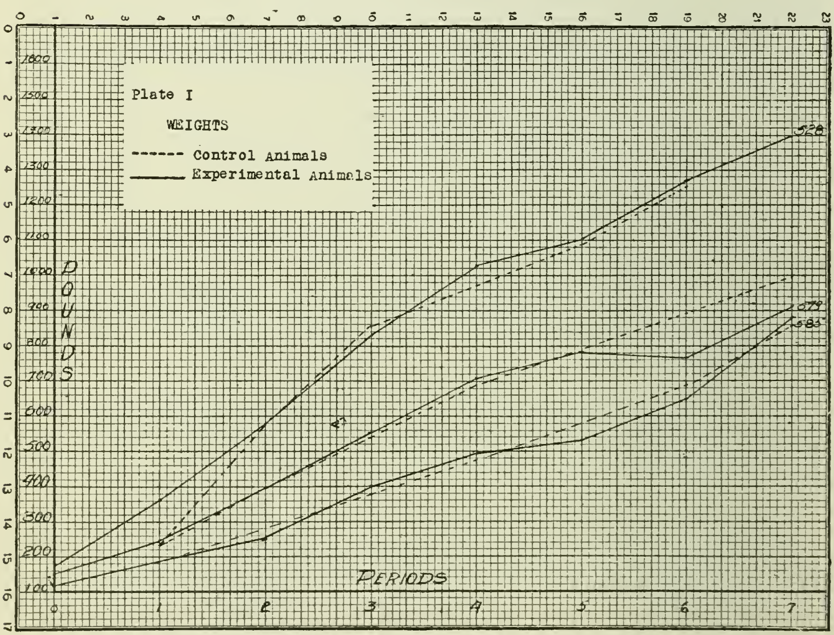

Fig. 1.—Weights—Comparison of control animals and experimental animals.

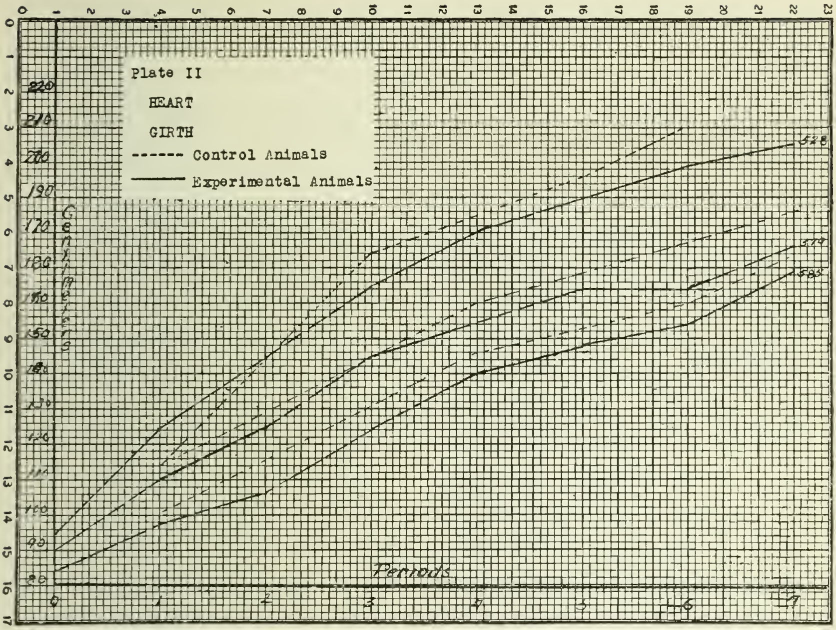

Fig. 2.—Heart Girth—Comparison of control animals and experimental animals.

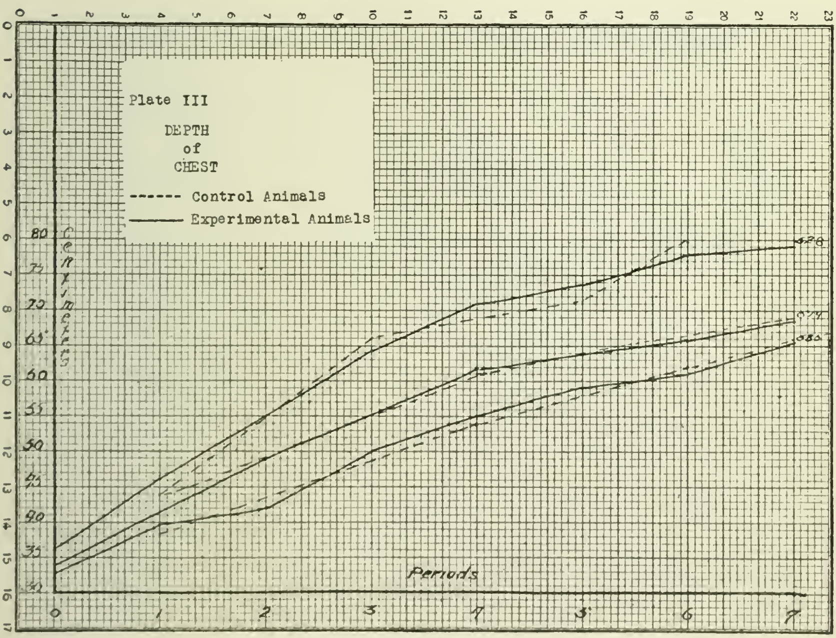

Fig. 3.—Depth of Chest—Comparison of control animals and experimental animals.

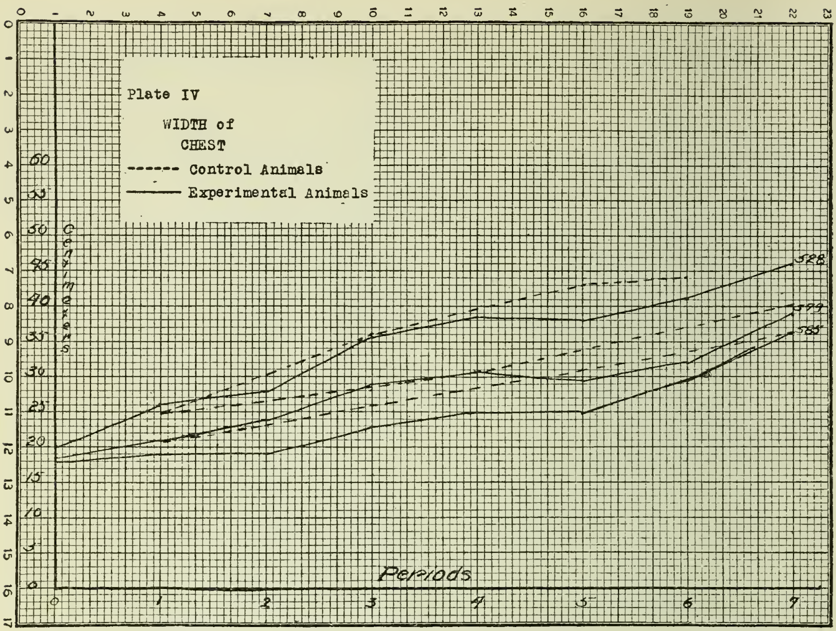

Fig. 4.—Width of Chest—Comparison of control animals and experimental animals.

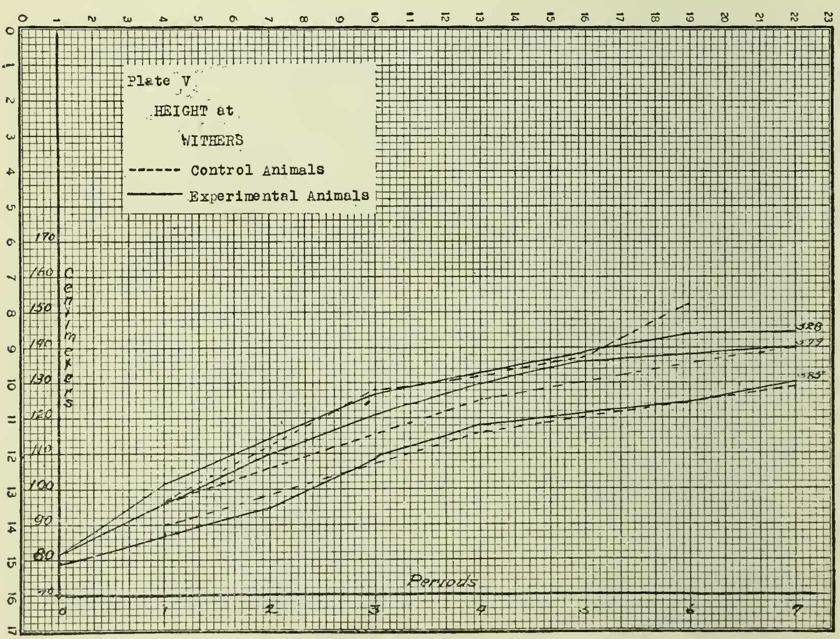

Fig. 5.—Height at Withers—Comparison of control animals and experimental animals.

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AGRICULTURAL EXPERIMENT STATION

RESEARCH BULLETIN 52

SCARRED ENDOSPERM AND SIZE INHERITANCE

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JULY, 1922

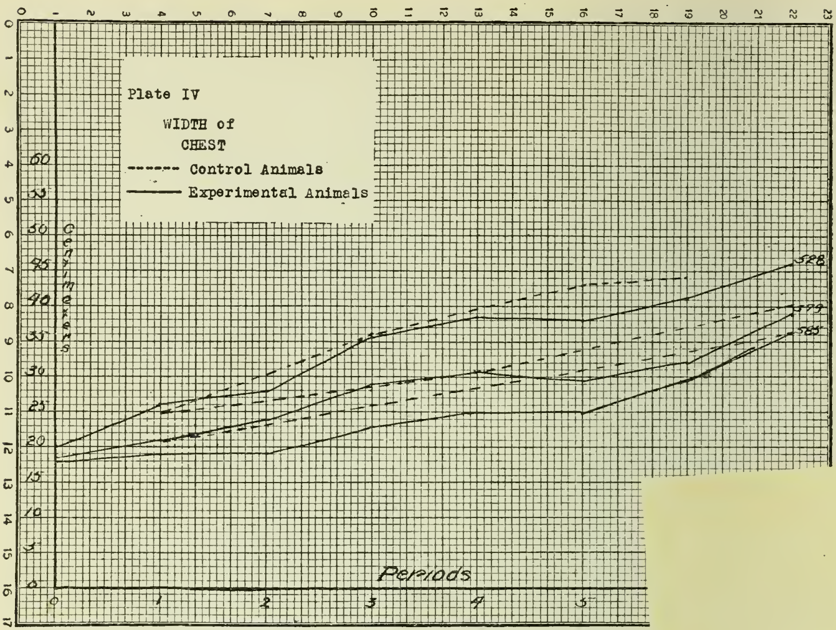

Fig. 4.—Width of Chest—Comparison of control animals and experim

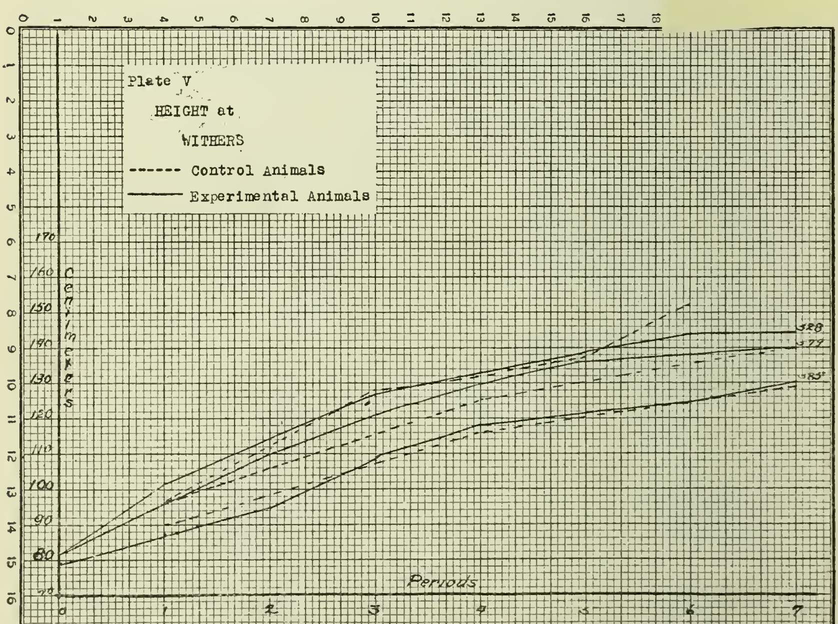

Fig. 5.—Height at Withers—Comparison of control animals and experimental animals.

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
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SCARRED ENDOSPERM AND SIZE INHERITANCE IN KERNELS OF MAIZE

(Publication authorized June 1, 1922.)

COLUMBIA, MISSOURI
JULY, 1922

UNIVERSITY OF MISSOURI

COLLEGE OF AGRICULTURE

Agricultural Experiment Station

Scarred Endosperm and Size Inheritance in Kernels of Maize

William H. Eyster*

In the summer of 1920 the writer found in a field of corn in central Pennsylvania a number of plants with striking chlorophyl patterns which are unlike any that have yet been described. These plants were numbered and marked in the field so that they could be identified at harvest time. The matured ears were sent to the writer at the University of Missouri by Mr. Webster Snyder in whose field they were discovered. Plantings were made from each ear in the greenhouse the following winter and the seedlings were found to be entirely green. One plant from each ear was grown to maturity in the greenhouse and self pollinated. In the summer of 1921 field plantings were made from the original ears and also from the self pollinated greenhouse ears. The F_2 progenies segregated plants with the chlorophyl patterns of the original plants together with a number of other characters, including a pistillate plant similar in appearance to tassel ear (Emerson, 1920) and the endosperm character described in this paper, which has been designated *scarred endosperm.*

The field plantings of 1921 were made at the Missouri Agricultural Experiment Station as part of a project in the genetics of maize carried on in the Department of Field Crops.

DESCRIPTION OF SCARRED ENDOSPERM

Maize kernels with scarred endosperm can usually be recognized on the ear, even though the kernels are so closely arranged that only the crowns are visible. The scarred kernels are not so large as the normal kernels on the same ear and are commonly pinched off so that they are somewhat similar in appearance to kernels with "rough identation".

The scarred character can more easily and certainly be recognized upon examination of the abgerminal surface of the kernel. Its external appearance is that of a scar left after the healing up of a deep wound.

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In Fig. 1 are shown camera lucida drawings of a number of kernels with scarred endosperm. In Fig. 2 are similar drawings of two scarred kernels from which the pericarp overlying the abgerminal surface was removed. The nature of this endosperm character can best be seen from the drawings. It is an irregular cavity in the endosperm on the abgerminal side of the kernel. The cavity consists in a crater-like excavation near the crown with divergent and often branched furrows extending towards the base of the kernel.

The pericarp over the crater-like excavation near the crown nearly always collapses and causes the kernels to have a *rough indentation.* Occasionally a kernel is found with the pericarp over the crater of the cavity in the form of a blister.

Scarred Endosperm and Size of Kernel.—Scarred kernels are uniformly smaller than normal kernels. In Fig. 3 is shown a crown view of a series of representative normal kernels (upper row) and scarred kernels (lower row) which were taken from the same ear. In Fig 4 is shown the same series of kernels, as in Fig. 3, but from the side. These figures show in a general way the relative differences in size between normal and scarred kernels of maize.

Scarred Endosperm and Thickness of Kernel.—The most conspicuous size difference between normal and scarred kernels is in the thickness of the kernels. Thickness here refers to the distance between the germinal and abgerminal surfaces of the kernel. The thickness of each kernel of individual ears segregating normal and scarred kernels was measured by using a sliding caliper rule and tabulated as shown in Table 1. Readings were made to the nearest one-half millimeter. The measurements were made by clamping the caliper over the end of the kernel at a uniform distance from the crown.

The distributions given in Table 1 show that for each ear the normal kernels are thicker than those with scarred endosperm. The mean thickness of normal kernels from individual ears varies from 3.856 to 5.722 millimeters. The mean thickness of the scarred kernels from the same ears varies from 3.100 to 5.360 millimeters. The mean difference in thickness of the normal and scarred kernels from the ears studied varied from 0.295 to 0.823 millimeter. The mean thickness of the normal kernels of the eight distributions listed in Table 1 considered collectively is 4.500 ± 0.144 millimeters. The mean thickness of the scarred kernels of these distributions is 3.926 ± 0.258 millimeters. The normal kernels are 0.574 ± 0.295 millimeter thicker than the scarred

kernels. In Fig. 5 are given curves which show graphically the variation in thickness of the normal and scarred kernels. These curves represent the total frequencies of the distributions listed in Table 1.

Scarred Endosperm and Weight of Kernel.—The kernels of each ear studied were weighed individually to the nearest milligram and tabulated as shown in Table 2. In every case the mean weight of the normal kernels is higher than the mean weight of the scarred kernels from the same ear. The mean weights of the normal kernels from the ears studied varied from 251.92 to 341.10 milligrams. The mean weights of the scarred kernels from the same ears varied from 232.70 to 329.60 milligrams. The differences in the means of the individual ears varied from 1.24 milligrams for ear 1243-2 to 19.13 milligrams for ear 1238-16. In order to obtain a general expression of the mean weights of the normal and scarred kernels the distributions in Table 2 are considered collectively. The mean weight of the normal kernels from the eight ears is 274 milligrams and the mean weight of

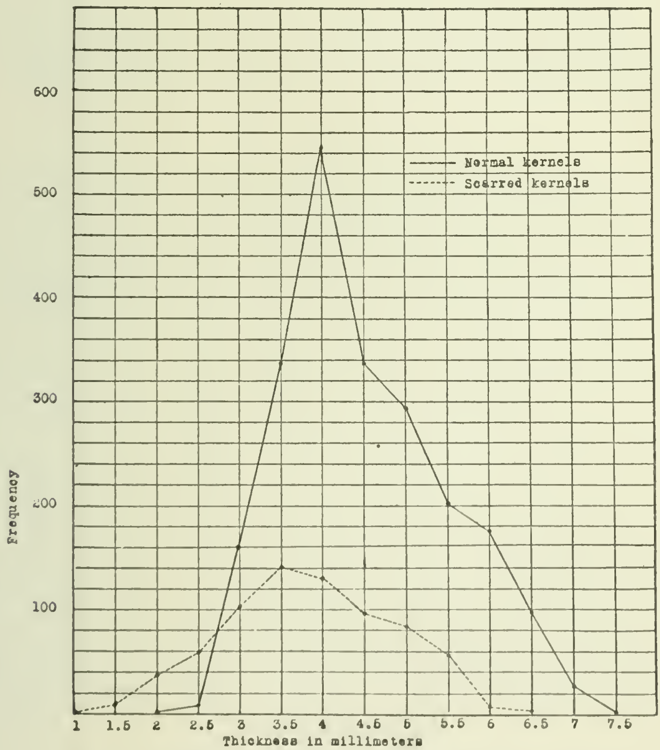

Fig. 5.—Variation in thickness of normal and scarred kernels.

the scarred kernels is 259.57 milligrams. This is a difference of 14.43 ± 1.29 milligrams. In Fig. 6 are curves of variation in weight of normal and scarred kernels when the eight distributions of Table 2 are considered collectively. In many respects these curves are similar to those for thickness of kernel given in Fig. 5.

The normal and scarred kernels respectively of each ear were weighed *en masse* with the results given in Table 3. From these total weights average kernel weights were obtained that do not involve the errors due to the separate weighing of the individual kernels. The average kernel weights are in fairly close agreement with the mean weights as given in Table 2.

The normal and scarred kernels from ear 1243-2 differ only slightly in average thickness and have approximately the same kernel weight. The mean weight of the normal kernels is given in Table 2 as 1.24 milligrams greater than that of the scarred kernels. The average weight, however, of the normals was found to be 1.36 milligrams less than the average weight of the scarred kernels. For the other ears the average weight of the normal kernels varies from 2.17 to 20.63 milligrams heavier than the scarred kernels taken from the same ear. The

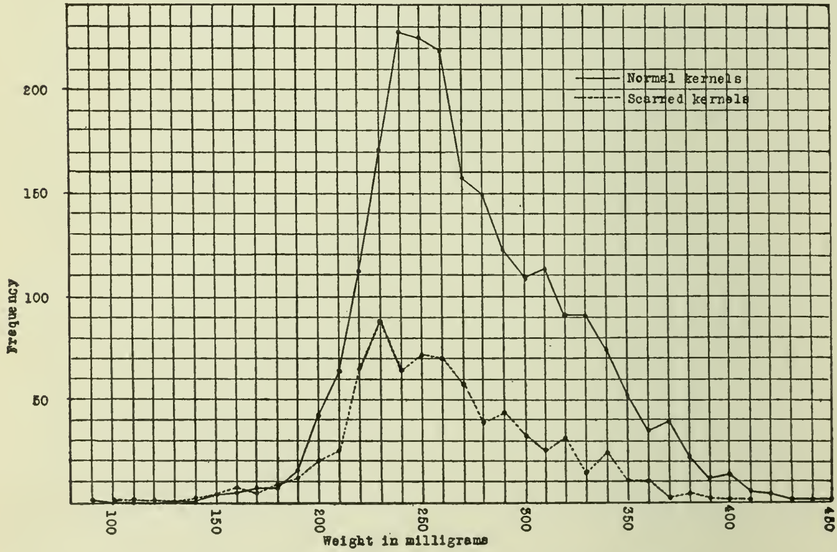

Fig. 6.—Variation in weight of normal and scarred kernels.

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Numbe	Descrip	90	1	450	Total	Mean	Difference
1238-16	Normal	1		--	384	288.07	
	Scarred	--		--	139	268.94	19.13
1243-2	Normal	--		--	424	233.94	
	Scarred	--		--	145	232.70	1.24
1243-8	Normal	--		1	340	312.12	
	Scarred	--		--	121	300.17	11.95
1243-13	Normal	--		--	301	260.86	
	Scarred	--		--	128	249.84	11.02
1243-7	Normal	--		--	181	341.10	
	Scarred	--		--	24	329.60	11.50
1245-6	Normal	--		--	422	251.92	
	Scarred	--		--	128	237.03	14.89
1245-7	Normal	--		--	58	287.93	
	Scarred	--		--	25	284.82	3.11
1245-8	Normal	--		--	85	255.65	
	Scarred	--		--	36	247.22	8.43
Total	Normal	1		1	2195	274.00	
	Scarred	--		--	746	259.57	14.43

Table 2.—F_2 Kernels of the Cross Normal X Scarred

Pedigree Number	Description	Thickness of Kernels in Millimeters														Total	Mean	Difference
		1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5			
1238-16	Normal ------	--	--	1	4	10	43	93	77	73	32	27	17	10	--	387	4.637	.572
	Scarred ------	--	1	5	5	11	28	32	25	17	8	5	1	--	--	138	4.065	
1243-2	Normal -------	--	--	--	1	28	95	167	54	37	23	11	3	--	--	419	4.123	.332
	Scarred ------	--	1	2	5	28	41	39	12	7	6	5	--	--	--	146	3.791	
1243-6	Normal ------	--	--	--	--	3	12	26	30	15	17	29	23	2	--	157	5.070	.815
	Scarred ------	--	--	--	1	3	9	13	7	10	4	1	1	--	----	49	4.255	
1243-8	Normal ------	--	--	----	--	5	23	69	62	69	62	41	12	3	--	346	4.860	.484
	Scarred ------	--	--	4	5	5	10	26	26	19	13	9	--	--	--	117	4.376	
1243-13	Normal --------	--	--	--	1	13	43	86	72	49	16	14	9	3	--	306	4.433	.823
	Scarred ------	--	--	11	13	25	25	15	14	13	6	1	--	--	--	123	3.610	
1245-6	Normal ------	--	--	--	3	104	118	102	33	22	18	9	6	3	--	418	3.856	.756
	Scarred ------	1	6	15	29	32	27	5	4	3	2	1	--	--	--	125	3.100	
1245-7	Normal ------	--	--	--	--	--	3	4	2	15	15	19	8	2	3	71	5.655	.295
	Scarred ------	----	--	--	--	--	1	1	4	6	7	0	4	2	--	25	5.360	
1245-8	Normal ------	--	--	--	--	--	1	1	7	14	19	23	18	5	--	88	5.722	.379
	Scarred ------	--	--	--	--	--	--	1	3	12	11	6	2	--	--	35	5.343	
Total	Normal ------	--	--	1	9	163	338	548	337	294	202	173	96	28	3	2192	4.500	
	Scarred ------	1	8	37	58	104	141	132	95	87	57	28	8	2	--	758	3.926	.574

Table 1.—Thickness of F_2 Kernels From the Cross Normal X Scarred

Number	Descrip	Weight of Kernels in Milligrams																																			Total	Mean	Difference
		90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390	400	410	420	430	440	450			
1238-16	Normal	1	0	0	0	1	1	3	3	5	1	4	4	7	11	19	18	19	27	20	40	29	27	21	30	24	18	12	11	7	5	5	5	3	2	0	1	--	384	288.07	
	Scarred	--	1	1	1	1	1	1	2	1	3	4	4	4	3	5	10	8	14	8	7	13	9	8	8	8	4	5	3	0	1	1	--	--	--	--	--	--	139	268.94	19.13
1243-2	Normal	--	--	--	--	--	--	1	1	1	4	8	24	37	73	80	67	54	36	22	9	5	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	424	233.94	
	Scarred	--	--	--	--	--	--	1	0	0	1	2	6	12	32	41	11	18	10	7	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	145	232.70	1.24
1243-8	Normal	--	--	--	--	--	--	--	--	--	--	--	1	4	5	2	2	3	8	10	21	40	43	50	34	32	31	22	13	7	9	0	1	1	0	0	0	1	340	312.12	
	Scarred	--	--	--	--	--	--	--	--	--	--	1	2	1	2	4	4	4	1	7	11	15	16	11	12	4	12	3	5	2	1	1	1	--	--	--	--	--	121	300.17	11.95
1243-13	Normal	--	--	--	--	--	--	--	--	--	--	1	4	8	5	20	42	45	47	44	41	18	12	9	3	1	1	--	--	--	--	--	--	--	--	--	--	--	301	260.86	
	Scarred	--	--	--	--	--	2	0	1	2	1	1	2	1	8	15	17	18	22	18	8	5	4	0	3	--	--	--	--	--	--	--	--	--	--	--	--	--	128	249.84	11.02
1243-7	Normal	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	1	1	3	3	5	10	14	14	29	22	17	11	25	8	6	7	1	2	1	--	--	181	341.10	
	Scarred	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	1	1	1	4	4	0	5	2	2	1	2	--	--	--	--	--	--	--	24	329.60	11.50
1245-6	Normal	--	--	--	--	--	--	--	--	--	1	0	3	4	11	45	89	91	88	51	24	10	2	2	1	--	--	--	--	--	--	--	--	--	--	--	--	--	422	251.92	
	Scarred	--	--	--	--	--	--	2	3	0	2	3	4	5	18	19	17	22	17	9	4	2	0	0	1	--	--	--	--	--	--	--	--	--	--	--	--	--	128	237.03	14.89
1245-7	Normal	--	--	--	--	--	--	--	--	--	--	--	1	0	2	0	0	4	3	3	5	8	6	10	8	4	2	2	--	--	--	--	--	--	--	--	--	--	58	287.93	
	Scarred	--	--	--	--	--	--	--	--	--	1	0	0	0	0	1	1	0	0	4	3	3	3	2	2	2	3	--	--	--	--	--	--	--	--	--	--	--	25	284.82	3.11
1245-8	Normal	--	--	--	--	--	--	--	1	1	1	2	5	5	5	5	8	8	9	4	7	8	7	7	1	1	--	--	--	--	--	--	--	--	--	--	--	--	85	255.65	
	Scarred	--	--	--	--	--	--	--	1	2	0	1	2	2	2	3	4	2	6	3	0	5	0	0	2	0	1	--	--	--	--	--	--	--	--	--	--	--	36	247.22	8.43
Total	Normal	1	0	0	0	1	1	4	5	7	7	15	42	65	112	171	227	225	219	157	150	123	109	113	91	91	74	53	35	39	22	11	13	5	4	1	1	1	2195	274.00	
	Scarred	--	1	1	1	1	3	4	7	5	8	12	20	25	65	88	64	72	70	57	38	44	33	25	32	14	25	10	10	3	4	2	1	--	--	--	--	--	746	259.57	14.43

data in Table 3 show a greater difference in weight of normal and scarred kernels for some ears than the data in Table 2.

Table 3.—F_2 Kernels From the Cross Normal X Scarred

Pedigree Number	Normal Kernels			Scarred Kernels			Difference
	Number	Total weight in mgs.	Average kernel weight in mgs.	Number	Total weight in mgs.	Average kernel weight in mgs.	Average kernel weight in mgs.
1238-16	387	108880	281.34	138	37700	273.19	8.15
1243-2	442	102325	231.50	124	28875	232.86	—1.36
1243-7	185	52200	337.57	25	8200	328.00	9.57
1243-8	345	107775	312.10	119	36200	304.20	7.90
1243-13	299	80850	270.40	126	32240	255.87	14.53
1245-6	420	89750	213.69	126	24325	193.06	20.63
1245-7	60	17650	294.17	25	7300	292.00	2.17
1245-8	87	21750	250.00	35	8650	247.14	2.86
Total	2225	581180	261.20	718	183490	255.56	5.64

INHERITANCE OF SCARRED ENDOSPERM

The factor pair for scarred endosperm is designated by the symbols S_c s_c.

F_1 Generation.—F_1 kernels from the cross *scarred x normal,* or its reciprocal, have normal endosperm.

F_2 Generation.—When F_1 plants are self pollinated, ears are produced which have normal and scarred kernels in ratios approximating 3 : 1. In Table 4 are recorded the numbers of normal and scarred

Table 4.—F_2 Kernels of the Cross Normal X Scarred

Pedigree Numbers	Normal kernels	Scarred kernels	Total	Ratio per 4
1238-16	390	138	528	2.955 : 1.045
1243-2	442	124	566	3.124 : 0.876
1243-7	185	25	210	3.524 : 0.476
1243-8	345	119	464	2.974 : 1.026
1243-13	299	126	425	2.814 : 1.186
1245-6	424	128	552	3.072 : 0.928
1245-7	60	25	85	2.828 : 1.172
1245-8	87	35	122	2.853 : 1.147
Total observed	2232	720	2952	3.026 : 0.974
Total expected	2214	738	2952	3.000 : 1.000

Deviation 18 ± 15.88

kernels taken from eight ears of F_1 plants that had been self pollinated. The ratios of the individual ears vary from 2.814 : 1.186 to 3.524 : 0.476. The average ratio for all the kernels from the eight ears is 3.026 : 0.974. The total numbers observed were 2232 normal and 720 scarred kernels. This is a deviation from the expected distribution of 18 ± 15.88 kernels.

F_3 Generation.—A field planting under family number 1238 was made from a self pollinated ear that segregated kernels with scarred endosperm. Twenty-one F_2 plants were grown to maturity. Three of these were wholly pistillate plants. The remainder were self pollinated and produced ears with kernels as indicated below:

	Kernels all Normal	Normal and Scarred kernels	All scarred Kernels
Observed	6	9	3
Expected	4.5	9	4.5
Deviation	1.5	0	—1.5

These numbers are small but are in close agreement with expectation.

SUMMARY AND DISCUSSION

Scarred is a new endosperm character in maize which consists in an irregular cavity in the endosperm on the abgerminal side of the kernel. Kernels with scarred endosperm usually have a *rough indentation.* Scarred kernels have been compared in thickness and weight with normal kernels and it is evident both from the general appearance of the kernels and from the data given in this paper that scarred kernels are smaller than the kernels with normal endosperm. Scarred endosperm is inherited as a simple Mendelian recessive character. Correlated with scarred endosperm is a difference in size of kernel that is apparently due to the same factor.

Emerson and East (1913) found in their study of quantitative characters in maize size differences, such as height of plant, length of ear, and size of kernel, to be due to multiple factors. Such quantitative characters, however, are not always due to multiple factors. A difference in size, or in any quantitative character, between certain individuals may be due to multiple factors, but a similar size or quantitative difference between certain other individuals may be due to a single factor. Thus differences in height of plants are commonly due to a number of factors, but a large number of height dif-

ferences in maize plants have already been found that are due to single factors. As examples may be mentioned *dwarf* and *anther ear* (Emerson, R. A., and Emerson, S. H., 1921), *brachytic* (Kempton, 1920) and others from the cultures of the writer and other workers in corn. By inter crossing these different types, progenies can be produced which segregate a number of factors for height of plant, and size inheritance becomes quantitative. The same principle may be applied to other quantitative differences.

Scarred endosperm represents a difference in size of kernel which is quantitative, but due apparently to a single factor. In this respect it is similar to size differences in seeds of beans observed by Johannsen (1913). In one of his pure lines Johannsen found a mutant with a longer seed than the parent stock. Seed length of this mutant bean was found by Leitch (1921) to be inherited as a single Mendelian character. Johannsen (1913) also found in his cultures a broad bean which, when crossed with the type, gives an F_2 progeny of 1 type : 2 intermediate : 1 broad.

It is reasonable to expect that maize plants will be found with other quantitative differences than height of plant and size of kernel that are inherited as simple Mendelian characters.

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Fig. 1.—Maize kernels with scarred endosperm.

Fig. 2.—Maize kernels with scarred endosperm. The pericarp has been removed from these kernels to show the nature of the scarred endosperm.

Fig. 3.—Kernels with normal endosperm (upper row) and scarred endosperm (lower row) from the same ear.

Fig. 4.—Kernels with normal endosperm (upper row) and scarred endosperm (lower row) from the same ear.

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THE RELATION OF TEMPERATURE TO BLOSSOMING IN THE APPLE AND THE PEACH

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Relation of Temperature to Blossoming in the Apple and the Peach

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Observation of the responsiveness of plants to certain temperatures and of the poleward progress of vegetative activity more or less concurrently with the advance of warm weather led to the formulation many years ago of the doctrine of thermal constants. According to this theory a given stage in the development of any plant is reached when that plant has received a certain amount of heat, regardless of the time required or of the temperatures involved. For each plant and for each successive stage there was assumed to be a definite heat requirement, which generally received a mathematical expression in the form of so-called "heat units." The unit was a degree on one of the several thermometer scales. However taken, temperature observations were generally reduced to terms of average or mean daily temperatures. The readings for all the days involved in the period in question were combined and the sum called the "thermal constant," since it was assumed to be constant for the plant wherever and whenever grown. Units based on this system may be designated "day-degrees" to distinguish them from the "hour-degrees" obtained by computation from hourly temperatures.

Enunciated first, probably, by Reaumer[29] in 1735, the original conception has been modified by later workers. Adanson[2] pointed out that temperatures below freezing do not reverse plant activity and discarded them from his summations. Others used as bases of calculation some still higher temperature, at which vegetative activity supposedly began. The number of heat units for one day was obtained by subtracting the base temperature from the actual —mean or maximum as the case might be—thermometer reading for that day; consequently this has been called the "remainder system." Later graduated values were assigned to various temperatures in recognition of accelerated growth at certain temperatures. The Livingstons,[22] particularly, have worked out a scale of weighted temperature values based on the principle of Van't Hoff and Arrhenius, pointing out, however, that the purely physical processes involved in growth are not governed by this principle. This system they called the "exponential." More recently Livingston[21]

evolved a third system called "physiological", based on Lehenbauer's observations of root growth in maize at various temperatures. This system differs from the others in that it recognizes an optimum temperature above which the values assigned decrease. It is put forward, evidently, only as tentative, since Livingston states several qualifications of its applicability.

Progress in plant physiology and particularly the recognition that numerous factors influence plant growth have modified the original conception of thermal constants. Numerous objections to the original conception have been stated aptly by Schimper,[31] and its rigid application is not often attempted, except in the use of growing season summations to characterize various regions, as exemplified by Merriam's[24] work on life zones, and Swingle's[33] on the date palm. Ihne,[18] though inclined to consider phenological observations a measure of the weather, expressly repudiates the assignment of definite thermal constants to any plant.

Unfortunately there has survived a supposed connotation between the old thermal constant conception and phenology which has retarded the study of phenological observations in ways that might otherwise have been attempted. One purpose of the present paper is to point out how the thermal constant conception, though full recognition be accorded the many objections to it, still may furnish, in connection with phenological observations, a valuable tool in the study of the response by plants to some of the factors composing climate. The comparative meagerness of the available data and the limited number of localities they represent preclude the possibility of formulating much that is conclusive, and this paper can be regarded only as suggestive of what might be attempted with abundant data for the same plant under many conditions.

PHENOLOGY OF FRUIT TREES IN NORTH AMERICA

Systematic observations on the blossoming of fruit trees at various points in North America began, perhaps, in 1817 when Bigelow[7] compiled a list of the dates of blossoming of the peach at various points from Fort Claiborne, Alabama, to Montreal. Early reports of the Smithsonian Institution and of the Army Signal Service, the forerunner of the present Weather Bureau, contain many scattered observations on blossoming dates. Following the recog-

nition of the importance of cross pollination in many fruits, blossoming data have been published by a number of agricultural experiment stations. Since these were intended merely to show the overlapping in blossoming seasons of horticultural varieties, complementary temperature data are not ordinarily available and study of them shows little beyond: (1) a general similarity in sequence of species and of varieties, (2) differences between places in the average lengths of the blossoming seasons and in the intervals between the blossoming of the several fruits, and (3) a general, though not uniform, recession of the blossoming dates with increased latitude and altitude.

The Initial Date.—Those who have attempted to fit thermal constants to phenological observations on perennial plants have found much perplexity in fixing an initial date for temperature summations. Some have computed from leaf fall in the previous autumn, some from the coldest period of the winter (which is, in many cases, early in February) and some from the date when the average daily temperature rises above the freezing point. Others, as Fritsch,[15] have considered the precise date of little importance and have used January 1, as a matter of convenience. This is, perhaps, the most commonly used starting point.

It is interesting that in many plants heat summations from this date to blossoming are not the same everywhere. Waugh[34] found in 1898 a general tendency for blossoming at lower summations in the north with the "American wild plum", than in the south. More pronounced differences are evident in the summations for the Late Crawford peach at Pomona, California, and at Wauseon, Ohio, shown in Table 1. These are compiled from reports of the California Agricultural Experiment Station[9, 10, 11] and from the Mikesell records.[25] Though the California figures are calculated from monthly means of daily maximum temperatures and the Ohio figures from daily maximum readings, errors arising from this cause must be slight in proportion; and the great differences shown in heat summations to blossoming actually exist. The highest summation from January to blossoming for any of the 27 years of the Ohio records is 925, considerably below the lowest shown here for Pomona and the minimum for Wauseon is barely more than one-fourth the maximum for Pomona.

TABLE 1.—HEAT SUMMATIONS IN DAY-DEGREES (MAXIMUM ABOVE 43) FOR THE LATE CRAWFORD PEACH FROM JANUARY 1 TO BLOSSOMING IN OHIO AND IN CALIFORNIA.

Year	Wauseon, Ohio		Pomona, California	
	Date of first blossoming	Day-degrees	Date of first blossoming	Day-degrees
1894	Apr. 17	745	Mar. 15	1222
1895	May 2	860	Mar. 2	1266
1896	Apr. 23	650	Mar. 20	2217
1902	Apr. 29	804	Apr. 1	2329
1903	....	....	Mar. 25	1895
Average	(27 yrs.)	732	(5 yrs.)	1786

There may be, then, a considerable and consistent inequality in heat summations from January 1 to blossoming for the same fruit grown at points differing considerably in climate. This is in accord with observations of Palladin,[27] who records similar differences in many plants at Brussels and at Petrograd; these differences were much more pronounced in the early blossoming than in the late blossoming plants. According to one view, advanced by Linsser[20] the total heat requirements for any stage of plant development are not identical at all places, but their proportion to the total heat summation of the year is everywhere constant. In other words, there is supposed to be an acclimatization so that the same function may be performed with less heat at one point than at another, but require the same proportion to the total for the year at all points. This hypothesis appears untenable, in some cases at least, since this numerical ratio between the accumulation to ripening in the peach and the total for the year varies widely, from 48.8 per cent in Alabama to 83.1 in Massachusetts.[16] Furthermore, it does not take into account seasonal variations at the same point. Seeley[32] found great fluctuations from year to year in heat accumulations for various epochs in the Late Crawford peach at Wauseon, Ohio. In some years the minimum accumulation was 70 per cent of the maximum for the same period, in another 50 and in one, only 38. Evidently, then, Linsser's constant or "aliquot" will not explain such differences as those in summations in California and in Ohio from January 1 to blossoming. Finally, since heat accumulations at one point may vary considerably from year to year, if carried to ex-

tremes this hypothesis implies a rather remarkable prescience in the plant.

The differences between localities in heat accumulations to blossoming may be due in part to different normal temperature distributions. Price[28] demonstrated an acceleration in blossoming of peach and plum with high temperatures; yet his data show that the twigs held at the lower temperatures, though they required a longer time for blossoming, actually received in some cases less total heat (in day-degrees). In some localities it is possible that even before blossoming there occur temperatures high enough to exercise an inhibitory effect, or, perhaps, the winters are not cold enough to make subsequent high temperatures fully effective. Twigs of ash and linden cut before the end of the rest period were kept by Weber[35] in a dormant state in a warm greenhouse for 15 months; at the end of this time most of the buds opened normally.

VARIABILITY IN SUMMATIONS TO BLOSSOMING

Since fruit bud differentiation in several fruits is first evident about July 1, it has been suggested that summations should be computed from this time to blossoming in the following spring. If this date is used for beginning computations on the apple and on the plum in Wisconsin, there is apparently a closer agreement from year to year than when summations are made from January 1; this has been interpreted to indicate July 1 as the proper starting point.[30] Much of this apparent agreement, however, is due to the tendency of meteorological elements to average alike over long periods. Summations calculated from July 1 to the following May 1, the approximate date of fruit bud opening, fit very nearly as closely as those figured to the dates of actual blossoming. The ratio between the smallest summation and the largest is, in the Doney plum, 86.8 per cent; in the calendar summations, the check, it is 82.9 per cent.

The very fact that the Doney plum came into blossom in 1904 with 4,494 day-degrees from July 1 while in 1901 the accumulation was 5,174, or 680 more, suggests that in the latter year some heat was received when it was ineffective in forwarding blossoms or was received in surplus quantities or that at some periods in the cycle heat is not a controlling factor.

Indeed, something of the sort may be deduced from the data published by Sandsten. If the summations from successive dates

be averaged and their respective mean deviations determined, it becomes evident that the ratio betwen the average of the summations and the mean deviation (in other words, the variability of the summations) changes and that it does not diminish in strict accordance with the tendency of meteorological values toward greater uniformity with increasing time. This is shown in Table 2, arranged from Sandsten's data for the Forest Garden plum, where the ratio just mentioned is designated the coefficient of variability. The "coefficient of variability" used in this paper is calculated from the mean, rather than from the standard, deviation, to lessen the effects of extreme variations.[37]

TABLE 2.—HEAT SUMMATIONS IN THE FOREST GARDEN PLUM AT MADISON. WISCONSIN, 1900-1905 INCLUSIVE.
(Compiled from data by Sandsten[30])

To blossoming from	Mean of summations	Average deviation	Coefficient of variability
July 1.	4836	181	3.74
Aug. 1	3608	157	4.35
Sept. 1	2416	71	2.93
Oct. 1	1540	97	6.29
Nov. 1	893	80	8.96
Dec. 1	678	61	9.99
Jan. 1	667	70	10.49
Feb. 1	662	71	10.72
Mar. 1	653	63	9.64
Apr. 1	523	58	11.08
Sept. 1 (omitting Nov., Dec., Jan., and Feb.)	2159	50	2.31

The significance of these coefficients is more apparent if they are studied beginning with the coefficient for January 1. On either side of this (December and March) are lower values, signifying greater agreement in summations beginning at other times and suggesting that temperature accumulations from this date are not altogether effective in advancing blossoming. In summations beginning March 1 there is closer agreement; and the high variability from April 1 may be interpreted to mean that advancement toward blossoming has begun, in some years at least, by that time. The difference in coefficients between November 1 and October 1 is striking and suggests that, beginning possibly about November 1, the temperatures received are not ordinarily effective. The greatest agreement in summations in the whole series is in those

dating from September 1; the low coefficient at this point is remarkable. If, however, the November, December, January and February temperatures are omitted the coefficient of variability in summations from this date is diminished even further.

From August 1 and July 1, though these months in themselves usually show relatively slight variability in their temperature summations, the coefficients of variability are higher. Their low value as compared with that of March is due to the longer period covered, and their significance is probably slight.

Here, then, though caution must be observed against inferring too much, there seems to be reason to consider tentatively for this fruit at Madison: (1) that temperature deficiency during July and August is not a limiting factor in any ordinary season, (2) that it becomes in some measure a limiting factor during September and October, (3) that temperature is ineffective during November, December, January and February, possibly because there is not enough heat received to have any appreciable effect and (4) that about March 1 it again becomes for a time a determining factor. Under other conditions, of course, very high temperatures may become limiting.

Even though these indications be true for the Forest Garden plum, caution should be exercised in applying them to another plant, for example a Japanese plum, in Wisconsin, or to the same plum in another locality. In other words, significant dates for phenological data may conceivably differ with the plant and with the locality. Angot[3] carried this idea of flexibility to the extreme, stating that the significant date varied not alone with the plant and the locality but also from year to year. Evidence is introduced in this paper indicating the variation of the significant date with plant and with locality; as to the yearly variation in the same plant and in the same locality the evidence is less clear. If, however, the chemical composition of the plant be considered to have an influence, as seems quite plausible, the effective date may vary as well. Furthermore, the stage of blossom development attained in the fall has been shown by Magness[23] to vary from year to year in the same variety. Consequently some variation in opening in the spring might be expected even in seasons that present practically the same temperatures.

THE APPLE AND THE PEACH IN OHIO

A study covering a number of seasons at one point has cer-

tain advantages over studies of a few seasons at many points. If, for example, the date when temperatures become effective be conceived to vary from place to place there is no satisfactory way of ascertaining this date from scattered observations unless the minimum accumulation to blossoming observed at any point be subtracted from the accumulations at other points and the dates computed from the day-degree remainders. This is, in effect, shaping the problem to fit the answer. In observations at one point over a series of years a certain degree of variation in other limiting factors is presumably reduced and if there is any validity in the thermal constant conception it should appear in observations of this sort.

The publication by the United States Weather Bureau of the Mikesell records,[25] comprising phenological observations on numerous plants at Wauseon, Ohio, over a period of 30 years, together with daily meteorological records, makes possible a rather critical comparison of heat accumulations and phenological observations.

Since these records cover a longer period than any other available data they are analyzed here and used in the study of the records of the Missouri Agricultural Experiment Station, which cover a much shorter time.

Methods Used.—Heat accumulations may be measured in various ways. In the work reported here the simple summations of temperature to blossoming, both maximum and mean, above several thermometric points, were computed. In addition one series was computed on the exponential system. For each series the yearly summations were averaged, the mean deviations from the averages determined and variability coefficients derived by dividing the mean deviations by the averages of the total accumulations. Occasional trials showed no material relative changes in coefficients resulting from the use of standard or mean deviations. The coefficients derived by the several methods are shown in

Table 3.—Variability Coefficients of Heat Summations From January 1 to Blossoming at Wauseon, Ohio, as Calculated on Different Bases.

Base	System	Apple	Peach
32°F. Max.	Remainder	7.69	8.26
43°F. Max.	Remainder	8.79	9.80
50°F. Max.	Remainder	10.48	12.73
43°F. Mean	Remainder	12.20	16.06
40°F. Max.	Exponential	10.38	9.97

The magnitude of the variability seems to vary inversely with the number of units involved; for this reason the lower variability resulting from the use of 32° as the base point is not necessarily significant. Since this comparison did not show any base-point or system to be markedly superior to any other, the series based on maximum temperature above 43° was chosen for most of the further computations. This system appeared to give intermediate values and its results would be comparable with other work which has been based on the same temperature.

Temperature observations taken according to conventional meteorological methods are not true records of plant temperatures and since the disparity between the two varies no corrections can be applied. For present purposes, however, since in sunshine twigs are generally warmer than the air, maximum air temperatures probably approximate those of the plant more closely than mean air temperatures. For other seasons or for other temperature ranges or in other climates mean temperatures might be preferable. However, even on summer stages for the peach at Wauseon, Seeley[32] found less variation in computations involving maximum than in those involving mean temperatures, though it is true this lower figure may be due to the larger number of units involved.

Calculations.—Though it seems unlikely that heat deficiency is a limiting factor with apples or peaches in Ohio during the summer months, computations were made from July 1 to blossoming the following year. From these figures the summations from other dates to blossoming were readily secured and the respective variability coefficients determined. As a check on these, summations to April 28 and to May 7, the average blossoming dates of the peach and of the apple, respectively, were similarly computed. These may be considered as measures of the independent variability of the weather and are valuable for comparison with the variability to the actual dates of blossoming.

If heat accumulations are plotted vertically and a horizontal scale be adopted for time such that the spread of the projections of blossoming dates on the abscissa is equal in length to the spread of the projections of the accumulations on the ordinate, mathematical expression of the trend of the line connecting blossoming dates is possible. This is, in effect, done when the coefficient of variability in accumulations to blossoming is divided by the coefficient of variability to the average date of blossoming. With per-

fect uniformity in total day-degrees to blossoming the line would be horizontal; with perfect uniformity in totals to a given date the line would be vertical. With an equal degree of uniformity in both it would be at a slope of 45°. This would be the case were coefficients of variability to blossoming and to average date of blossoming equal.

In short, the numerical ratio obtained by dividing the coefficient of variability in summations to blossoming by the coefficient of variability in summations to average date is the tangent of the angle with the horizontal made by a smooth line connecting the dates of blossoming. When this ratio is above one, the angle is greater than 45° and nearer vertical. In other words, the agreement is closer with the average date than in the total accumulations.

Accordingly the figures in the columns headed "Tangent" in Table 4 are in reality tangents of slopes of lines connecting the graphical positions of the blossoming dates. The value 0.94 for the apple indicates a slope of approximately 43° for this line—practical neutrality. The value 0.51 indicates a slope of approximately 27.° In the peach the 1.47 value indicates a slope of 56°, nearer vertical than horizontal. However, even without expression in degrees, the tangents serve for comparison.

TABLE 4.—VARIABILITY COEFFICIENTS OF HEAT ACCUMULATIONS FROM VARIOUS DATES TO BLOSSOMING IN THE APPLE AND IN THE PEACH AT WAUSEON, OHIO.

Beginning date	Apple			Peach		
	To actual blossoming	To average date of blossoming	Tangent	To actual blossoming	To average date of blossoming	Tangent
July 1	4.55	5.36	0.85	5.27	5.00	1.05
Aug. 1	5.63	6.45	0.87	6.22	6.34	0.98
Sept. 1	7.37	7.86	0.94	8.04	7.66	1.05
Oct. 1	9.33	11.11	0.84	9.71	10.59	0.92
Nov. 1	11.08	13.80	0.80	7.77	14.33	0.54
Dec. 1	13.65	15.47	0.88	9.55	16.94	0.56
Jan. 1	8.79	15.64	0.56	9.80	16.37	0.60
Feb. 1	8.48	15.78	0.54	11.34	16.73	0.68
Mar. 1	9.79	16.76	0.58	13.40	17.51	0.76
Mar. 15	7.93	15.51	0.51	14.91	15.60	0.95
Apr. 1	14.70	15.79	0.93	25.22	17.09	1.47

Indications.—The lower the tangent the more significant, presumably, is the coefficient for the corresponding period. Consequently the low variability coefficients for the summer and autumn months lose their weight and those of some of the later dates become more significant.

An interesting difference between the apple and the peach is revealed by inspection of the tangents. The lowest value in the peach is in the summations figured from November 1; in the apple the lowest value is in the figures dating from March 15. This difference seems to indicate that, under the conditions obtaining at Wauseon, high temperatures during winter are effective in promoting growth in the peach, but not in the apple.

In the apple the period of effective temperatures seems more definitely fixed than in the peach. From January 1 to March 15 in the apple the tangents change but little, with the smallest figure on March 15. It should be considered, however, that heat accumulations are small during this time and can affect the total variability but little. Other things equal, such changes as do occur as the date of summations moves backward should, through augmenting somewhat the total of day-degrees involved, reduce the variability. Therefore even the slight difference in tangents shown may be significant in the apple. The occurrence of the lowest figure on March 14 does not signify that the rest period ends then. It is, in a sense, an average date and means that, broadly speaking, advancement starts in half the years at that time. Consequently the end of the rest period must be earlier.

In the peach, the succession of low values is in the reverse order and so far as this array affords evidence, the decrease from January 1 or December 1 may be due merely to the longer period and the consequently greater total of units involved. In either case, however, it seems clear that the peach becomes responsive to high temperature earlier than the apple and that its earlier blossoming is not necessarily due to a lower total requirement of heat. The low temperature of the ordinary winter at Wauseon would keep the trees dormant and microscopic study of buds for several years might show no development during this time, unless the period of investigation happened to include a mild winter. Dormancy of the peach in the north and in the south may be quite different; in the one case imposed by low temperature and in the other by the rest period. Johnston[19] found that the moisture content of peach buds in Maryland increases after January 1

in a definite relationship to the "sum of the effective daily mean temperature above 43°."

Seasonal Differences.—Illustration of the difference between the two types of fruit is found in the graphs of heat accumulations from January 1 in 1890 and in 1912, shown in figure 1. These years are selected because they represent respectively the maximum and the minimum accumulations of heat from January 1 to March 1. In 1912, with little accumulation of heat prior to April 1, the apple came into blossom very close to the peach both in time and in heat accumulations. This year, in fact, marked the

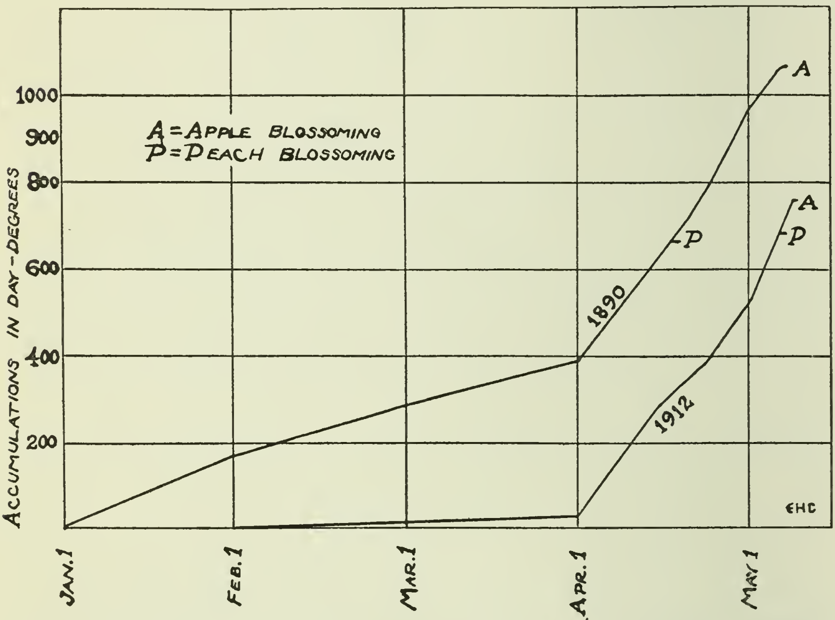

Fig. 1.—Blossoming of peach and apple in years of maximum and of minimum accumulation on March 1, at Wauseon, O.

lowest summation to blossoming for the apple. In 1890, with considerable heat accumulation throughout the winter months, the peach came into blossom earlier, but with substantially the same heat accumulation as in 1912. The apple, however, though its date of blossoming was nearly the same as in 1912, had received 300 day-degrees more of heat. This difference is about the same as the margin by which the accumulation to April 1 in 1890 exceeded that of 1912. This may be interpreted to signify that in 1912 practically all the heat received came when it was

effective, while in 1890 much of it was ineffective for the apple. Apparently the peach started from dormancy earlier than the apple in 1890, while in 1912 there was little difference, because the low temperatures held both dormant.

Since these two winters were so widely different, it seems logical to infer that localities with average winters differing (as do these extreme types) would show for regions with mild winters a considerable spread in blossoming season between the peach and the apple—well known to be the case—while those with cold winters would show little or no difference. In extreme cases the peach and the apple may bloom simultaneously. This condition occurred at Wauseon in 1895, following a cold January and February and was closely approached in other years, invariably following winters of small heat accumulations. Indeed, in 1912 which, according to Hedrick[17] was not an unusual blossoming season, at Geneva, New York, blossoming in the apples began a day ahead of the peaches. The same phenomenon occurred in 1905 at Columbia, Missouri. The variations sometimes reported in the sequence of blossoming in other fruits may be due to similar causes.

If a certain validity be assumed for the thermal constant conception, the rather wide difference from year to year in the summations from any given date to blossoming suggest that the higher figures may be due to accumulations occurring during periods when they are ineffective or in greater quantities than can be fully effective—and of course other factors than temperature may intervene. To facilitate comparison, data for the years of maximum and of minimum accumulations from January 1 to blossoming in the peach and in the apple are arranged in Table 5. It is interesting and significant that these years are not identical for the two fruits, only three duplications occurring. In both fruits the minimum accumulations from January 1 to blossoming average practically the same in relation to the maximum, but here the similarity stops. In the peach the years of lowest summation from January 1 to blossoming generally succeed periods of considerable accumulation in November and December, the accumulations preceding the years of minimum accumulation being in fact 141 per cent of those preceding the maximum. In the apple it is apparently a matter of indifference, since the November and December accumulations preceding the minimum and the maximum years average practically the same. It should be stated that the

Table 5.—Analysis of Accumulations in Years of Greatest and of Lowest Summations From January 1 to Blossoming in the Peach and in the Apple at Wauseon, Ohio.
(In day-degrees)

Year	Jan. 1 to blossoming	Previous Nov. 1 to Jan. 1	Jan. 1 to Mar. 1	Jan. 1 to Mar. 15	Mar. 15 to blossoming
			Peach		
			Years of Minimum Summations		
1910	632	363	14	112	520
1908	588	180	18	104	484
1900	627	305	86	100	527
1896	650	286	50	57	593
1891	594	296	125	142	452
			Years of Maximum Summations		
1902	804	184	52	144	660
1898	834	266	72	198	636
1895	860	222	31	45	815
1893	853	150	13	104	749
1887	870	195	80	213	657
			Apple		
			Years of Minimum Summations		
1912	752	195	6	6	746
1908	791	302	18	104	687
1905	787	290	13	15	772
1896	779	286	12	57	722
1886	803	217	83	196	607
			Years of Maximum Summations		
1901	1005	259	42	66	939
1894	1217	323	124	324	893
1890	1052	296	294	327	725
1889	1056	308	70	148	908
1887	1079	195	80	213	866
			Averages		
			Peach		
Min.	618	286	59	103	515
Max.	844	203	49	141	703
			Apple		
Min.	781	258	26	56	707
Max.	1081	276	122	215	866
			Minimum in per cent of Maximum.		
Peach	73.2	141	120	73	73
Apple	72.2	93	21.0	26	82

two years of greatest heat accumulation in November and December were followed by crop failures in the peach, constituting two out of the three in the 30 years of record. These facts, together with the low variability coefficient in the peach summations from November 1 (Table 4) indicate that rather marked accumulations of heat in November and December have some influence in the forwarding of Late Crawford peach blossoms toward opening, but are not important in the King apple.

Johnston[19] found that the relation between temperature accumulations from January 1 and moisture content of peach fruit buds, though constant in any one year, varies from year to year; and that "certain conditioning influences that are operative during or preceding dormancy apparently 'predetermine' the exact relationship between air temperature and the moisture content of the buds for the period following dormancy."

The averages in Table 5 show an excess of heat during January and February of the years of minimum accumulation for the peach, but inspection of the detailed figures shows that this is of doubtful significance, since it is due to a high value in one year only. The low ratio of the minimum to the maximum years (21 per cent) in the apple, however, apparently signifies that the apple is unresponsive at this time and that heat accumulations during this period merely swell the total without having any marked effect in advancing the blossoms. The same negative relationship appears in the figures to March 15 for the apple (16 per cent) while the figures for the peach change markedly and assume the same relationship as the total accumulations. The similarity in the relationship in the peach of the years of maximum to those of minimum accumulations from January 1 to blossoming, from January 1 to March 15 and from March 15 to blossoming suggests that the same influences are operative during all three periods; in other words, that development is progressing. In the apple the change at this time is abrupt—from 28 to 86 per cent—the accumulations from March 15 to blossoming being more nearly alike as between maximum and minimum years than those from January 1 and closer than in the peach—86 as compared to 73 per cent.

Assuming, for the reasons given above, November 1 to mark the commencement of possible effective temperatures in advancing the peach toward blossoming and March 15 for the apple, data for the five years of maximum summations for these respec-

tive periods in each fruit are assembled in Table 6 to show their relation to the temperatures of October, September and August preceding.

TABLE 6.—TEMPERATURE SUMMATIONS FROM DATE OF POSSIBLE EFFECTIVENESS IN RELATION TO TEMPERATURE OF PREVIOUS MONTHS, AT WAUSEON, OHIO.

Year	Peach				Apple				
	Nov. 1 to blossoming	Oct.	Sept.	Aug.	Year	Mar. 15 to blossoming	Oct.	Sept.	Aug.
			Years of Minimum Accumulation						
1911-12	879	554	979	1203	1910-11	669	647	979	1245
1910-11	782	647	979	1245	1908-09	694	699	1202	1249
1907-08	768	380	932	1190	1907-08	687	380	932	1190
1906-07	878	326	1154	1326	1901-02	706	740	1063	1350
1890-91	890	502	839	1213	1885-86	707	430	952	1075
			Years of Maximum Accumulation.						
1897-98	1100	882	1270	1211	1900-01	939	940	1174	1448
1894-95	1082	620	1109	1361	1893-94	893	597	1048	1317
1893-94	1068	597	1048	1317	1888-89	908	476	958	1289
1891-92	1071	587	1201	1254	1887-88	903	460	990	1284
1883-84	1104	378	866	1137	1883-84	892	378	866	1137
				Averages					
Min. yrs.	839	481	977	1235	----------	693	579	1026	1222
Max. yrs.	1085	613	1099	1256	----------	907	550	1072	1295
			Minimum in per cent of Maximum.						
Peach	77	78	89	98		76	105	96	94

These figures suggest, though not very strongly, a tendency toward an association between lower temperatures in October and a low summation from November 1 to blossoming in the peach. In the apple there is little or no appearance of any relationship. This difference may possibly be associated with some effect of the high October temperatures in prolonging or of the low temperatures in breaking the rest period in the peach, while in the apple at this time they have, ordinarily, no apparent effect. However, since rainfall in September is likely to be important in connection with September and October temperatures, no clear evidence is afforded by the data in Table 6 as to the effects of October temperature, though the essential similarity in September and August summations indicates that temperature variations in these months have little effect on these fruits in this locality.

MISSOURI RECORDS

Rather complete phenological records of numerous varieties of apples and peaches were kept at the Missouri Agricultural Experiment Station from 1905 to 1918 inclusive, with the exception of the blossoming records for 1910. This was an early season and the records show most varieties in full bloom on March 28 but the dates of first blossoming are not recorded; consequently this year is omitted from calculations reported here.

Through the kindness of Mr. George Reeder, of the United States Weather Bureau, temperature records for the period covered by the phenological data have been made available. These observations were made at the Weather Bureau office, about one-fourth mile from the University Orchard in which the phenological observations were taken.

An interesting commentary on the hazards of peach growing in this section is the appearance of blossoming dates for peaches for only 8 of the 13 years of the record. Since the observations were made with considerable care it is safe to presume that no blossoms appeared in other seasons during this period. Compared with the 27 crops in 30 years at Wauseon, Ohio, and with the uninterrupted, though brief, sequence reported from Pomona, California, they suggest that this particular section may be termed a no-man's land for the common varieties of peach, being subjected to the hazards of both northern and southern types of winter injury, (extreme cold and untimely warm weather respectively) while regions north and south are subject ordinarily to only one form. Because of the scarcity of data no attempt is made here to study extensively the climatic relations of the peach in central Missouri.

The comparative brevity of the period for which data are available at Columbia increases the difficulty of formulating any hypothesis as to the periods of effective temperatures. Similarly, though data are available for a considerable number of varieties, the brevity of the record for each makes varietal comparisons rather uncertain. However, some generalizations seem safe. The warmer winter months at Columbia make the average heat summations up to the date of blossoming greater than those at Wauseon, though the difference is not so marked as that between California and Ohio for the peach. Since the comparison in Table 7 between summations at blossoming at Columbia and at Wauseon is between the King apple at Wauseon and the Fameuse at Colum-

TABLE 7.—AVERAGE TEMPERATURE ACCUMULATIONS (MAX. ABOVE 43°) FROM JANUARY 1 TO BLOSSOMING IN THE APPLE AT WAUSEON, OHIO, AND AT COLUMBIA, MO.

To	Wauseon, Ohio King Apple	Columbia, Missouri Fameuse Apple
February 1	36	122
March 1	72	261
March 15	127	389
April 1	254	646
Blossoming	912	950

bia, the actual difference in any one variety would be somewhat greater. It is interesting that Fameuse blossomed in 1895, apparently a normal season, on April 1 at Paso Robles, California, with a day-degree accumulation of 1421 from the first of January[9]; in 1902 the blossoming at Pomona, California, was on April 5 with an accumulation of over 2300 day-degrees[10] and in 1903 on April 15 with an accumulation of about 2273 day-degrees.[11]

Varietal Differences.—Of the varieties for which data are available for all the years of record, Minnesota, Fameuse and Primate are the earliest blossoming; Rome, Ralls and Ingram the latest. Data are presented in Table 8 showing the coefficients of variability in summations to blossoming in these varieties from dif-

TABLE 8.—VARIABILITY IN DAY-DEGREE SUMMATIONS FROM VARIOUS DATES TO BLOSSOMING IN THE APPLE AT COLUMBIA, MO., COMPUTED FROM MAXIMUM TEMPERATURES ABOVE 43°F.

	Oct. 1	Nov. 1	Dec. 1	Jan. 1	Feb. 1	Feb. 15	Mar. 1	Mar. 15	Apr. 1
Early blossoming									
Minnesota	7.82	8.95	8.96	9.41	8.98	8.21	8.68	16.78	....
Fameuse	7.91	8.21	8.32	9.15	9.15	7.99	7.69	13.45	....
Primate	7.48	8.81	9.28	10.90	10.24	9.51	10.41	15.56	....
Av.	7.77	8.66	8.85	9.75	9.46	8.57	8.93	15.26	....
Weather	8.33	11.87	16.58	18.11	20.89	20.09	22.46	18.41	....
Late blossoming									
Rome	7.61	9.27	9.27	10.32	10.49	10.18	9.82	8.41	29.65
Ralls	7.84	9.01	10.42	10.14	11.21	11.12	11.23	8.69	23.79
Ingram	7.58	9.01	7.68	8.15	8.63	9.60	8.76	9.62	27.74
Av.	7.68	9.10	9.12	9.54	10.11	10.29	9.94	8.91	27.06
Weather	6.65	8.50	9.46	9.37	10.62	9.89	9.88	7.01	15.15

ferent dates on the 43° maximum basis. The variability in the weather to average data of blossoming as compared with the Ohio figures is generally greater in the early blossoming varieties and lower in the late blossoming. Much of this difference may be attributed to the smaller number of years considered, since 1912 was marked by great deficiency in temperature until near the average date of blossoming for the early varieties, but was more nearly normal by the average date for the late blossoming varieties. Omission of this year from the record would reduce the variability in the summations to the average date of the early blossoming varieties very materially. The lower variability in the Columbia figures to the average date for the late blossoming varieties may be due to the greater number of day-degrees involved or it may be accidental. The probable error of the mean from January 1, is, for Columbia ±40, as compared with ±21 for Wauseon.

As they stand, the figures in Table 8 show, though not at all clearly, the same general tendencies in the early blossoming varieties as those appearing in the Wauseon data, with the apparently significant date earlier. Those for the late blossoming varieties, however, show no agreement greater than that in the weather to their average date of blossoming. The drop to 8.91 on March 15 might be significant were it not for the even lower figure (7.01) for the weather check. Though the low value of the latter is obviously accidental, it precludes the attachment of any significance to the former.

Another way of comparing these two groups of apple varieties is through coefficients of correlation between accumulations and the date of blossoming, somewhat after the manner used by Aoki and Tazika[4] in the sweet cherry. In this case any relationship would be shown by a negative correlation. As shown in Table 9 the correlation, wherever there is one, is stronger in the early

Table 9.—Coefficients of Correlation Between Heat Accumulations (Above 43°, Max.) and Date of First Blossoms in Apple at Columbia, Mo.

Period of accumulation	Early blossoming varieties	Late blossoming varieties
January	0.174±0.13	0.168±0.18
February	—0.369±0.16	—0.142±0.11
March	—0.856±0.05	—0.510±0.14
February 15—March 15	—0.473±0.15	—0.065

blossoming varieties. Since the time interval between the periods of accumulation considered and the blossoming is shorter in the early blossoming than in late blossoming varieties, there is less opportunity for disturbing variations in the unmeasured interval and the correlation would be expected to be greater in the former. However, even with this allowance, there seems some indication that the date of effective temperatures is earlier in the early blossoming than in the late blossoming varieties.

Different Temperature Basis.—Since it seems possible that the late blossoming of some varieties may be due to lack of response to certain temperatures which are effective with the early blossoming varieties, variability coefficients based on a higher minimum, 50°, are presented in Table 10. Here, curiously enough in view of the Wauseon results, the variability for the early blossoming varieties is generally decreased, though the variability of the weather is increased. The full significance of this is not clear though the study of the records for single years which follows may explain it in part. In the late blossoming varieties the variability in summations to blossoming generally decreases somewhat, while that of the summations to the average date increases. The changes are too slight, however, to be indicative. One possibly significant change is in the figures for March 15 where the variability increases enough to give the tangent a value of 0.7034. Of itself this is not sufficiently low to have much weight, but in con-

TABLE 10.—VARIABILITY IN DAY-DEGREE SUMMATIONS FROM VARIOUS DATES TO BLOSSOMING IN THE APPLE AT COLUMBIA, MO., COMPUTED FROM MAXIMUM TEMPERATURES ABOVE 50°F.

	Nov. 1	Dec. 1	Jan. 1	Feb. 1	Feb. 15	Mar. 1	Mar. 15	Apr. 1
Early blossoming								
Minnesota	10.55	8.45	8.31	8.59	9.81	10.59	15.96	....
Fameuse	10.04	8.78	9.47	8.61	7.45	6.92	13.37	....
Primate	9.42	9.38	8.95	7.81	8.41	8.30	13.12	....
Av.	10.00	8.87	8.91	8.34	8.56	8.60	14.15	....
Weather	14.44	20.69	21.45	24.22	24.09	25.86	23.17	....
Late blossoming								
Rome	11.51	9.34	8.96	9.50	9.34	8.94	8.42	34.14
Ralls	10.10	10.59	9.94	10.65	9.93	9.33	8.10	27.76
Ingram	10.61	8.69	7.72	8.46	9.36	8.89	10.65	31.73
Av.	10.74	9.54	8.87	9.54	9.54	9.05	9.06	31.21
Weather	8.73	9.80	8.28	10.10	10.81	10.66	12.88	21.07

nection with the condition shown for this date in Table 8 it may have some meaning.

Seasonal Differences.—Some interesting weather variations with related responses are shown by the graphs of yearly accumulations shown in figures 2, 3 and 4. These are grouped more or less at random, the chief aim being to present the years of peach blossoming in two diagrams.

The first four years of the record are shown in figure 2. Two of the four, 1906 and 1907, were rather high in accumulations to March 15 and diverged widely from that time; the 1905 curve

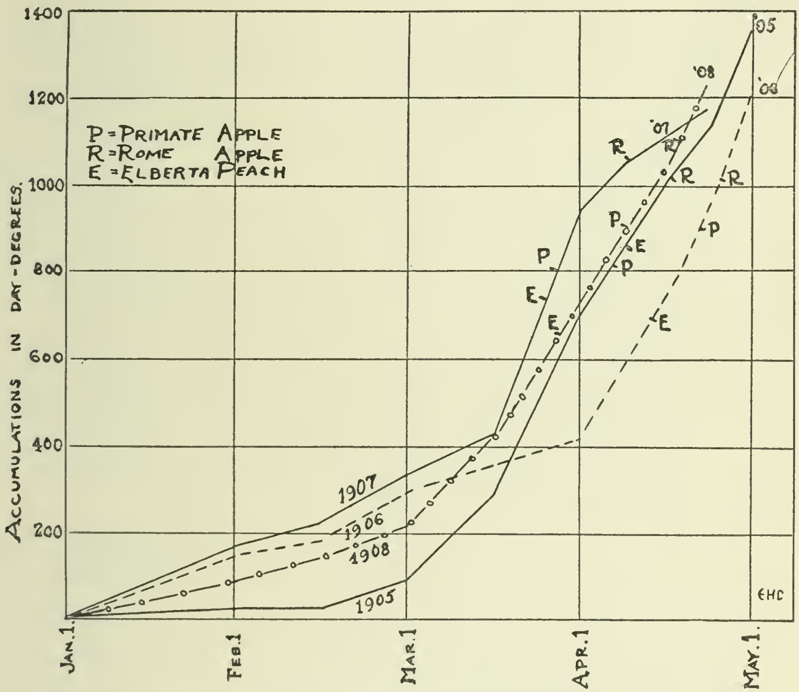

Fig. 2.—Accumulations (in day-degrees) to blossoming at Columbia, Mo.

shows a markedly low winter accumulation followed by rapid advance; 1908 is noteworthy for steadiness of the accumulation from March 1. Another interesting relationship is the identity of accumulations about March 15 of the two pairs of curves. The agreement in these pairs in the accumulations to blossoming for Rome and the agreement in summations from March 15 are remarkably close. The tangent in this case is 0.244. The agreement in Primate is even closer, the tangent being in fact 0.222, but the agreement is not within the same pairs as in Rome. In both cases

of blossoming at the lower summation the accelerating influence of high temperature is apparent in the steepness of the gradient.

The 1906 and 1908 curves are rather close to parallel for some time and blossoming of Primate occurs at the same level on them. The Elberta peach blossoms at a lower level on the 1908 curve. These curves crossed about March 10 and accumulations then were identical, but the more rapid rise from that point in 1908 evidently had more effect on Elberta than on Primate. Comparison of the 1905 and 1908 curves indicates the effect of the sharp rise after March 15 in hastening the development of the Primate blossoms.

In 1905 the Primate apple blossomed ahead of the Elberta peach. The arrangement in the figure shows that this was due to Elberta being late in blossoming rather than Primate being early. This was the year of very little accumulation until after March 1. Apparently the cold weather held the peach dormant until high temperatures could become effective on the apple, as in Ohio in 1912, shown in figure 1. It should be stated, however, that a considerable amount of winter-killing of buds occurred during the winter of 1904-1905 and that the blossoming of Elberta as recorded is doubtless later than it would have been with a full crop, since generally the more advanced buds are more readily killed. Furthermore, Chandler[13] mentions a mild form of winter injury which retards, but does not prevent blossoming. Even with this allowance, however, the closeness of Elberta and Primate is indicative of the influences mentioned.

It is interesting that Morgan[26] working at Ithaca, New York, reported the apple to start development earlier in the spring than the peach but that the peach rapidly overtook it. This might well be the case if the investigation were carried on in such years as 1905 or where the common season resembles the 1905 season. On the other hand Drinkard[14] in Virginia reported more advancement during the winter in the peach than in the apple. Assuming the peach to require higher temperatures than the apple it might start later than the apple in seasons that are cool, but with warm temperatures it starts before the apple.

In figure 3 are presented curves for the remaining years for which peach blossoming dates are available, with that for 1912 added for comparison. The successive spring freezes of 1921 destroyed apple blossoms so extensively that blossoming records were not taken, consequently the curve for that year is not car-

ried beyond the blossoming of Elberta, which occurred before any damage had been inflicted and is therefore reliable. At first glance the high accumulations for Elberta in 1909 and 1911 are outstanding and apparently inconsistent. These years, however, were characterized by a considerable amount of winter killing of buds, the damage in 1909 in Elberta at Columbia amounting, according to Chandler,[12] to 97.3 per cent. Data are not available on the extent of the damage to Elberta in 1911, but since it ranged from

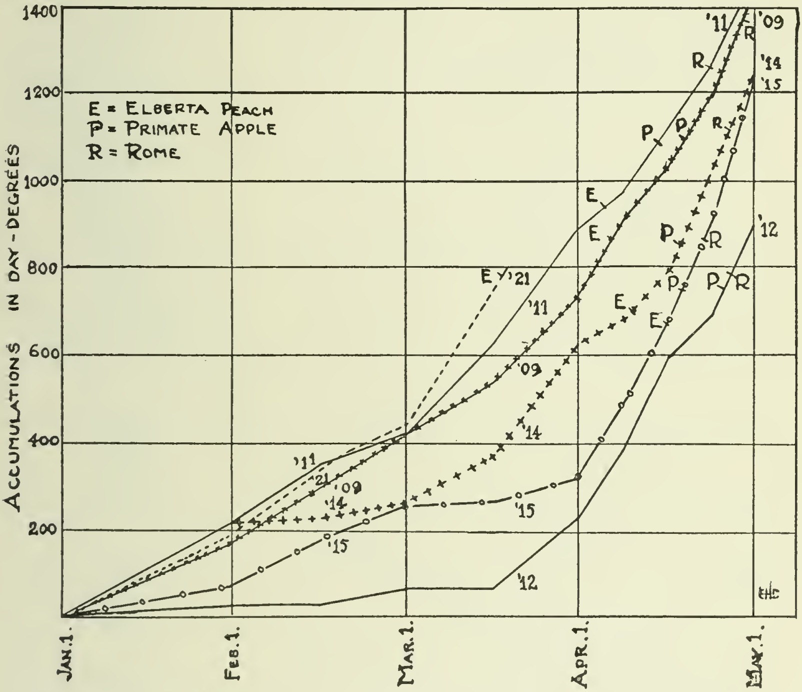

Fig. 3.—Accumulations (in day-degrees) to blossoming at Columbia, Mo.

29.8 per cent to 79 per cent in other varieties, it must have been considerable. These dates, then, represent the opening of only a very small portion of the total number of blossoms and these, presumably, those that were least advanced during the winter and would be the last to open in the spring. With these allowances, the line connecting the blossoming dates of Elberta would become nearly horizontal, signifying a rather close agreement in totals to blossoming.

In Rome the differences in day-degrees at blossoming are in the same order as the differences on March 15 with one exception.

This is on the 1909 curve where Rome seems unduly late in blossoming. Since yield records are not available for this variety the amount of bloom this year cannot be stated. That Rome was "out of step" in this case is shown by the fact that this was the only year in the record when Ingram blossomed ahead of Rome. If this were due to scarcity of crop so that the only blossoms appearing were terminals—as is sometimes the case—this discrepancy would be explained. However, even with this allowance, the agreement is very little greater in summations from March 15 to May 1.

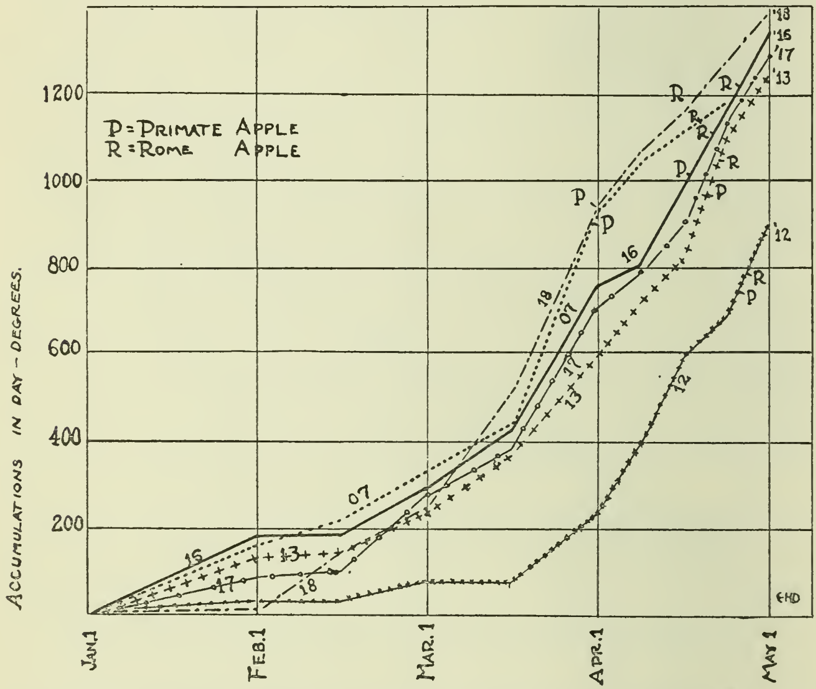

Fig. 4.—Accumulations (in day-degrees) to blossoming at Columbia, Mo.

In figure 4 are shown graphs for years in which no blossoming dates for the Elberta peach are available; to these 1907 is added because of its close similarity to 1918 after March 1. These graphs are strikingly similar, excepting the 1912 curve. In 1913, 1916 and 1917 Primate appears to have been retarded by a week of cool weather in early April, though its extreme lateness in 1917 can be only partly explained in this way. Here again, sparseness of the crop may be a partial explanation, since study of the spurs

of this tree in the orchard shows very little blossoming in that year. The blossoming of Rome at a comparatively low accumulation in 1913 may be explained by the rapid rise in temperature subsequent to April 15.

The evident retarding effect of the cold weeks in early April in 1913, 1916 and 1917 and the absence of influence of these weeks on Rome, though it is clearly responsive to high temperature, raises an interesting question. Since the buds of Primate, which was retarded, were more advanced at these periods than those of Rome, which apparently was not retarded, it seems quite possible that optimum temperatures vary as the buds advance toward opening. The decrease in the rate of the temperature rise in 1907 after Primate was in blossom and Rome presumably well advanced, seems to have had a retarding effect.

There is a rather strong trend toward uniformity in summations to blossoming in these curves, if 1912 be disregarded. This does not, however, necessarily signify that temperatures of January and February are effective, since the accumulations are very much alike on March 1 or even on March 15. Here again, plotting the curves with March 1 as the starting point or, for Rome, March 15, secures much greater agreement.

Considering all graphs shown, and making the allowances indicated, there is a rather marked tendency for uniformity in summations from January 1 to blossoming, in the Elberta peach. Where the uniformity appears in the blossoming of the apples it is accompanied by an approximate uniformity in the accumulations at some date subsequent to January 1. Nowhere, however, is there clear evidence pointing to uniformity or difference in the end of the rest period between the early and the late blossoming apples. The graphs in figure 3, contrasting warm springs with a very cold spring, suggest a difference in the rest period.

In Table 11 are assembled data showing the fluctuating difference between 30 varieties of apple for all the years of record. Included in this are all the varieties for which data are complete; in most cases the records are from the same trees throughout. The seasonal difference in dates of first bloom (range) is shown to vary from 5 to 27 days and the average deviation from 0.97 to 4.75 days. That this difference between the first and last blossoming variety is little more—or is even less—constant when expressed in terms of heat is shown by comparison of the maximum range in day-degrees (519) with the minimum (187). The gen-

TABLE 11.—VARIATIONS IN BLOSSOMING AMONG THIRTY APPLE VARIETIES AT COLUMBIA, MO.

Year	Days				Day-degrees			
	Aver. date of blos.	Range	Duration of bloom in earliest variety	Aver. devi-ation	Aver. accumu-lation	Range	Aver. devi-ation	Aver. daily acc. dur-ing blos.
1905	99.6	24	22	2.85	898.7	519	69.5	21.6
1906	111.2	13	12	1.69	926.4	415	51.1	31.9
1907	87.9	22	21	3.14	886.8	323	48.4	14.7
1908	101.4	14	12	1.87	943.6	342	45.1	24.4
1909	111.2	18	13	3.32	1191.3	419	52.3	23.3
1911	104.7	18	20	2.89	1109.8	380	61.4	21.1
1912	115.7	8	16	1.25	766.0	193	30.0	24.1
1913	109.5	12	12	1.80	964.9	315	48.6	26.3
1914	111.2	11	10	1.59	976.1	359	51.7	32.6
1915	111.0	5	6	0.97	879.6	187	36.4	37.4
1916	107.9	13	13	1.47	1059.1	279	40.3	21.5
1917	111.7	20	8	2.81	1100.0	313	63.4	15.6
1918	100.3	27	33	4.75	1087.3	418	69.1	15.5
Av.	106.4	15.8	14.5	2.34	983.8	343	51.3	23.8

eral accelerating effect of high temperature is evident in the average of the daily temperature accumulations during the three shortest ranges, 31.3,° and during the three longest, 17.3.°

No constant on the basis used here will measure the difference between blossoming in the earliest apple and the latest. It is quite likely that an exponential or a "physiological" system would measure this brief span more closely. It is, however, quite as probable that conditions before the blossoming of the earliest apples vary from season to season and that this event may find the late blossoming variety at various stages. When the early blossoming variety is not held back by unfavorable weather the late blossoming kind will lag behind; when the early blossoming variety is retarded the difference will be less, other things equal. This indicates a difference in date of effective temperatures. However, it is noteworthy that no matter how much the season is retarded and how small the range between the varieties, the early-blossoming kinds bloom first and the late-blossoming varieties bloom last. This indicates a difference in temperature requirements.

Leaf and Fruit Buds Compared.—Apparently the opening of blossoms and the unfolding of leaves respond somewhat differently to a given set of conditions. Bailey[5] says that in the southern states plum flowers "tend to appear wholly in advance of the leaves, and they are borne upon short stalks, or may be nearly or quite sessile. In the North, the flowers and leaves are generally coetaneous, and the flower stalks are usually longer." Ballard and Volck[6] report that spraying with nitrate of soda in February hastened the opening of flowers but not of leaf buds, in apples and pears. Table 12 shows the variability in summations to appearance of the first fully formed leaf at Wauseon, Ohio. Since the period of record is not identical with that for blossoming the figures are not strictly comparable. However, the differences between the values of the tangents in Tables 4 and 12 seem considerable enough to signify some difference between leaves and blossoms in their responses. In some years blossoms preceded leaves; other years showed the opposite condition.

Table 12.—Variability in Day-Degree Summations (Maximum, Above 43°) to Date of the Appearance of the First Fully Formed Leaf in the Apple at Wauseon, Ohio.

Summations beginning	Variability in summations	Variability in summations to average date	Tangent
September 1	7.30	7.47	0.98
October 1	9.05	10.23	0.88
November 1	10.21	15.74	0.65
December 1	11.74	17.69	0.66
January 1	11.90	18.60	0.64
February 1	11.28	17.73	0.64
March 1	11.41	17.63	0.65
April 1	16.42	19.09	0.86

The data for Columbia record a somewhat different phase of vegetative development, namely, the opening of the leaf buds. Very rare indeed in these records is the case where the opening of the first blossom precedes the opening of the first leaf bud; almost invariably the leaf buds open before the blossoms. The margin of difference varies, however. In three typical early blossoming varieties the average difference for 13 years is 7 days; in three typical late blossoming varieties it is 11 days. The late blossoming varieties blossomed on the average 13 days after the

opening of the first bloom; their leaves appeared, on the average, 10 days after the opening of the first leaf bud.

Evidence from Microscopic Examination.—Explanation of much of the lack of agreement among the variability coefficients of the several varieties represented in Tables 8 and 10 is found through microscopic examination of flower buds at various times during the winter. Typical photomicrographs of preparations made by Mr. V. R. Boswell are shown in Plates I, II and III. Oldenburg and Primate represent the earliest blossoming varieties; Rome, Daru and Cilligos the latest. The two last are included since they have been used extensively in the apple breeding work of the Missouri Station. Daru blossoms at about the same time as Ingram; Cilligos is the latest blossoming of all varieties under observation.

Plate I shows the stages reached by several varieties on February 2, 1920. Oldenburg is clearly more advanced than the other varieties. In the other cases, the correspondence between development on this date and the order of blossoming is not so close. Fameuse, the second earliest in blossoming, is no farther advanced than Daru, the second latest in blossoming. Gano and York, mid-season varieties, are apparently at the same stage as Cilligos, the latest of all.

In Plate II are shown the stages on three dates, November 2, 1921, January 28, 1922, and February 20, 1922, for three varieties, Oldenburg, Primate and Wealthy. The first two are distinctly early in blossominng; Wealthy might be classed either among the last of the early blossoming or among the earliest of the mid-season varieties. Here the advancement of Oldenburg in November is marked; this appears clearly to be a factor in its early blossoming since subsequent samples show relatively slight development. The other early blossoming variety, Primate, shows a quite different condition. Its November stage is not advanced; indeed, Daru, one of the latest blossoming, shows equal or greater pistil development on this date. Its changes through the winter, however, are notable and suggest that this variety has a factor producing early blossoming quite different from or more intense than that evident in Oldenburg. Wealthy, equally or more advanced in early November, does not develop as rapidly through the winter.

Plate III records the development of the buds in three late blossoming varieties sampled on the same dates as those of the

early blossoming varieties shown in Plate II. Daru, the second latest in blossoming of all the varieties shown, is among the more advanced on November 2. Its lateness is due apparently to its lack of responsiveness to temperatures with which Primate develops. Rome presents an anomaly in that it is perhaps the least advanced in November and apparently advances little or none to February 20; nevertheless it comes into blossom ahead of Daru and Cilligos.

The winter of 1921-1922 in Columbia was mild in the sense that there was little very cold weather. However, as measured in day-degrees above 43° it was not warmer than the ordinary season; the monthly accumulations from November to February inclusive being respectively 345, 167, 92 and 178. November accumulations were below the average (426) and December above (39), January somewhat below the average (122) and February somewhat above (139). The samples shown here, however, were gathered on February 20, when the accumulation for the month had reached 102 day-degrees only and before the warmest weather of the month. Consequently such development as is shown to be connected with temperature for this winter may be regarded as normal for this locality.

Evidently, then, early blossoming in apples involves at least two factors: first, the stage of advancement reached at the approach of winter, as exemplified by Oldenburg; second, ability to develop through the winter, as shown by Primate. Late blossoming, presumably, is due to the absence of both these factors or to the presence of strong inhibitors of the second. The ideal late blossoming variety as represented by Cilligos is backward in development in the fall and advances little through the winter. It is plausible that mixed inheritance of these factors gives the mid-season blossoming shown by the majority of commercial varieties, though Daru appears to have one factor for earliness despite its late blossoming. This seems the more likely since its crosses with Delicious now growing in the Experiment Station grounds include only very few late blossoming varieties, a smaller percentage than those shown by the majority of the crosses involving Ingram, another late blossoming variety.

The behavior of the late blossoming varieties indicates either a requirement of higher temperatures for advancement or the temporary presence of a development-inhibiting factor that is absent in the early blossoming kinds. If late blossoming is due to

a higher temperature requirement, the difference between late and early blossoming kinds should be diminished by forcing in a greenhouse. If late blossoming is due to the persistence of the rest period in some form these differences should decrease as the season advances. Table 13 shows the results obtained by forcing twigs of Primate (hypothetically without or over the rest period)and of Rome (hypothetically still in the rest period). The stages observed in the two varieties differ, but comparison is possible. Though the buds started March 3 were kept in a cooler house than that used for the two earlier lots, enough cooler apparently to retard Primate, Rome started in a shorter time. The lower temperatures actually retarded the early blossoming variety more than the late blossoming. This, with the progressive shortening of the period of forcing in Rome, indicates the rest period as a factor rather than a differential temperature requirement.

TABLE 13.—NUMBER OF DAYS INVOLVED IN FORCING BLOSSOM BUDS OF PRIMATE AND ROME APPLES, 1922.

Date forcing started	Days to blossoms open in Primate	Days to buds starting in Rome
February 16	17	15
February 25	14	14
March 3	20	13

Comparison of Plates IV and V shows that the difference between varieties are greater when they are forced in the greenhouse than when the buds develop in the orchard. This points in the same direction as the evidence just cited.

Other Considerations.—Analysis of the records of 42 trees for which data are complete shows no relation between the date of terminal bud formation on shoots and the date of spur blossoming in the spring, the correlation coefficient being 0.085 ± 0.04. It is possible, however, that comparison of trees under different cultural conditions might show a relation of this sort, though it is doubtful if it should not be considered an associated rather than a causative condition.

Incidentally the relation to cross pollination of differences in blossoming may be mentioned. Comparison of the figures in the column headed "Range" with those in that headed "Duration of bloom in earliest variety" in Table 11 shows that in eight years of the thirteen recorded the earliest variety was out of bloom be-

fore the latest blossoming came in. In two years the date of last blossom in the one and of first bloom in the other were identical. In one only was the overlapping sufficient to ensure abundant cross pollination. In this section, then, when very early blossoming kinds are planted with very late blossoming kinds, cross pollination can be ensured only by a third variety, intermediate in blossoming season. This will provide pollination for the early blooming kinds with its first blossoms and for the late blooming with its last blossoms. Most of the commercial varieties grown in Missouri fall into the intermediate class in blossoming and may be counted on with safety so far as cross pollination is concerned. However, it is possible that the reputation of the Rome for light bearing in Missouri, though in Ohio it has not met that objection, is due to the greater extent of the blossoming season in Missouri so that Rome may in some seasons be in bloom alone while in Ohio the difference ordinarily would be less marked.

Table 14 shows the blossoming dates of several peach varieties, selected to permit comparison with dates for the same varieties at points with winters considerably milder than those at Columbia. For compactness these are expressed in days of the year rather than of the month. Though the list for most years at Columbia is more extensive than those given for Alabama or California, the range in blossoming represented is less in every case. In other words, just as the blossoming of the apple in distinctly cold sections has a narrower range than at Columbia, so the peach at Columbia has a narrower range than at points farther south. Cool weather during the peach blossoming season at Auburn, Alabama, may have prolonged the season of 1911 to an unusual length, but the normal blossoming range of the varieties named in this paper is apparently as great or greater than the maximum recorded for Columbia.[36] The range shown for Pomona, California, is apparently normal for that point.

The slight difference between all varieties at Columbia in 1907, the year of earliest blossoming for which an approximately complete record is available, indicates that the rest period as a factor in the date of blossoming in the peach is not operative here. This was a year of rather high temperature from January on. A considerably greater number of varieties than is here reported showed almost as close agreement in blossoming in 1921, when the season was even earlier than that of 1907. Any differences in the rest period which might be concealed by the retarding effect

of an ordinary winter on the earliest varieties should become evident in these seasons of exceptionally high late winter temperatures, as soon as growth is possible. The third year of closeness in blossoming, 1906, was characterized by rather low accumulation during winter, with a rapid advance about the time of blossoming. The spread of the year of greatest range is due apparently to unequal winter-killing of blossoms and to the slow accumulation of temperature, which brought out minor differences in response to heat or merely delayed the opening of those varieties which had fewest buds. In warmer climates it seems quite possible that these differences in blossoming are due to differences in the termination of the rest period, particularly since the Peen-to peaches there blossom much earlier than those recorded in Table 14, and almonds in January or February.

TABLE 14.—PEACH BLOSSOMING DATES (IN DAYS OF YEAR) AT VARIOUS POINTS.

Variety	Columbia, Mo.									Auburn Ala.	Pomona Calif.			
	1905	1906	1907	1908	1909	1911	1914	1915	1921	1911	1894	1895	1902	1903
Alexander	98	102	82	90	101	95	--	--	--	--	78	76	--	88
Briggs Red	98	103	83	90	96	92	--	--	--	--	78	63	--	91
Carman	98	102	83	85	--	95	98	107	76	52	--	--	--	--
Champion	97	103	82	86	94	94	99	107	76	52	--	--	--	--
Chinese Cling	100	102	83	86	96	93	97	106	75	46	71	64	84	77
Crawford Early	--	102	82	80	96	93	96	108	--	35	74	62	91	84
Crawford Late	99	102	83	86	--	96	94	--	--	--	72	60	91	69
Elberta	98	102	82	85	95	92	97	107	74	45	--	--	--	--
Family Favorite	99	102	82	85	95	93	--	--	--	44	--	--	--	--
Foster	101	102	82	--	96	95	100	109	--	--	72	63	95	74
Globe	--	103	82	86	96	95	--	--	--	46	--	--	--	--
Heath Cling	97	104	82	84	95	96	103	--	--	--	72	66	91	69
Henrietta	102	103	82	88	97	--	--	--	--	--	--	65	--	--
Lemon Cling	--	102	83	88	96	93	103	105	--	--	--	73	--	--
Mayflower	--	--	--	--	--	95	100	105	--	57	--	--	--	--
Mountain Rose	--	--	--	--	--	--	98	107	75	--	76	60	91	77
Oldmixon Cling	98	102	82	86	96	97	.94	108	--	--	72	63	94	87
Oldmixon Free	98	102	82	85	95	95	97	--	--	--	84	66	95	74
Salway	98	103	83	85	96	92	103	107	76	46	73	66	61	91
Smock	91	103	82	86	95	101	104	--	--	52	79	63	--	77
Sneed	99	102	83	87	95	93	--	--	--	52	--	--	--	--
Susquehanna	102	103	83	86	--	96	--	--	--	50	72	63	--	69
Thurber	99	102	82	86	95	--	--	--	--	43	--	--	--	--
Yellow St. John	98	103	82	86	99	96	--	--	--	--	72	63	64	79
Range	12	4	2	11	8	10	10	5	3	23	14	17	35	23

SUMMARY

1. The amount of heat, as measured in day-degrees, received by peaches from January 1 to the time of blossoming, varies with the season and even more with the locality.

2. The agreement in temperature accumulations to blossoming from year to year at any one place varies with the length of the time for which they are measured indicating that ordinary temperatures are not always effective or that temperature is not always a limiting factor.

3. Variability in temperature accumulations from various dates to blossoming at Wauseon, Ohio, follows different orders in the King apple and the Late Crawford peach, indicating that the latter is responsive to high temperatures when the former is not.

4. The average temperature accumulation from January 1 to blossoming in the apple is somewhat greater at Columbia, Mo. than at Wauseon, Ohio, but much less than at Pomona, Calif.

5. Varietal differences in blossoming at Columbia, Mo., indicate that the early blossoming varieties of apple become responsive to ordinary temperatures earlier than the late blossoming. There are, however, some inconsistencies which are not explained by any mathematical analysis attempted.

6. Microscopic examination of blossom buds indicates that there are at least two factors governing the season of blossoming at Columbia, Mo. Oldenburg blossoms early chiefly because the buds are well advanced in the fall, Primate because the buds develop through the winter. Daru is well advanced in the fall but does not develop through the winter and blossoms late. Cilligos is backward in the fall and does not advance through the winter; it is the latest blossoming variety observed. The mid-season varieties apparently have a mixed genetic constitution in this respect.

7. Observations on branches forced in the greenhouse indicate that late blossoming is connected with rest period influences rather than with differential temperature requirements.

8. Varietal differences in the peach at Columbia appear to be masked, but may become evident farther south, in the same manner as differences apparent in the apple at Columbia are masked farther north.

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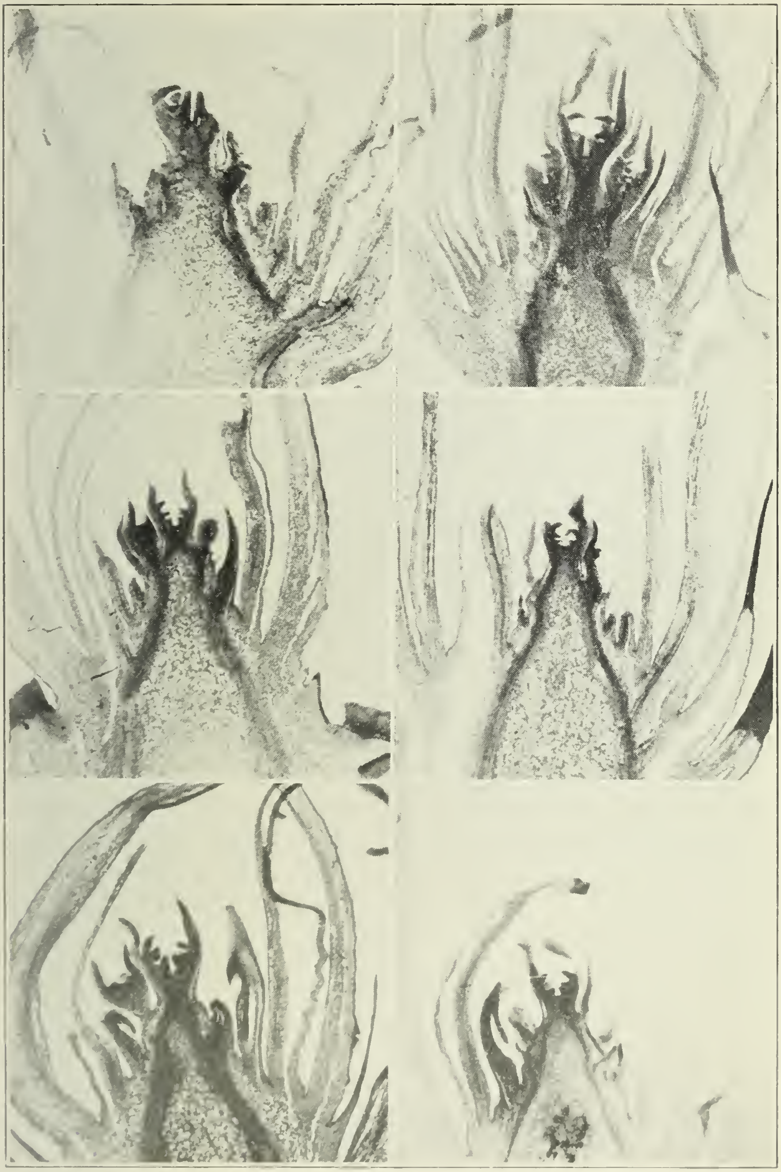

Plate I.—Blossom buds of apple on February 2, 1920.

Olderburg	Fameuse
Gano	York
Daru	Cilligos

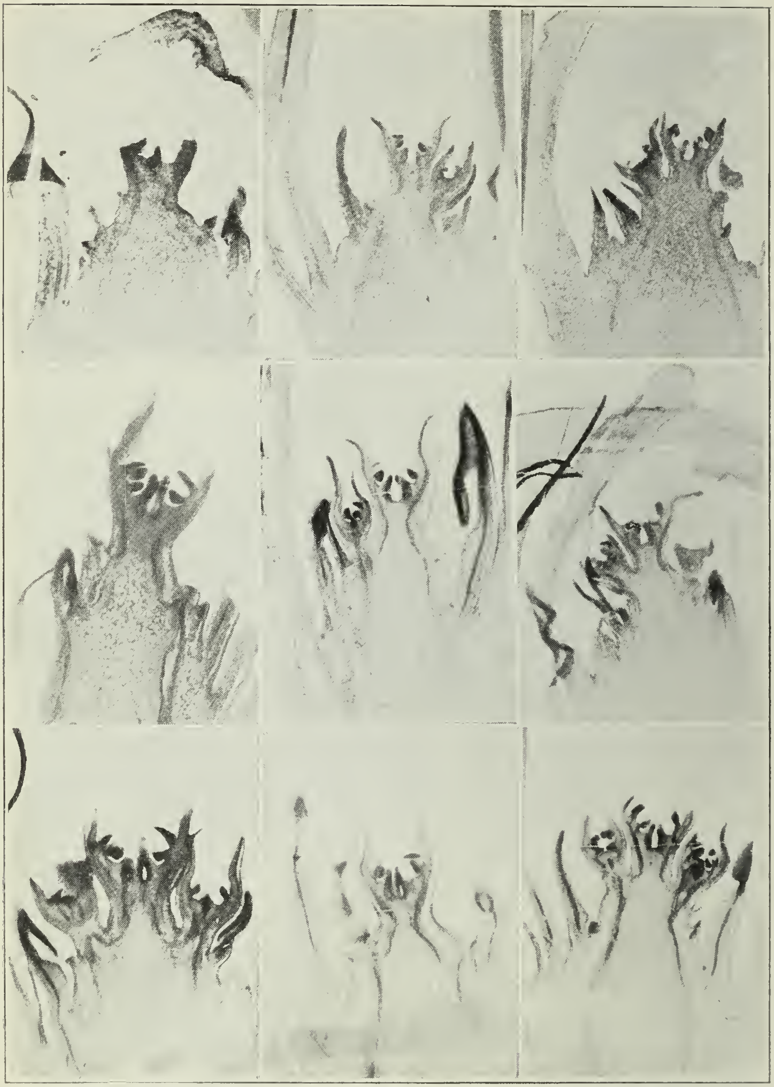

Plate II.—By rows: left to right, Oldenburg, Primate, Wealthy; top to bottom, November 2, 1921, January 28, 1922, February 20, 1922.

Plate III.—By rows: left to right, Rome, Daru, Cilligos; top to bottom, November 2, 1921, January 28, 1922, February 20, 1922.

Plate IV.—Buds developing out of doors, 1920. Left to right: Cilligos, Fameuse, Oldenburg.

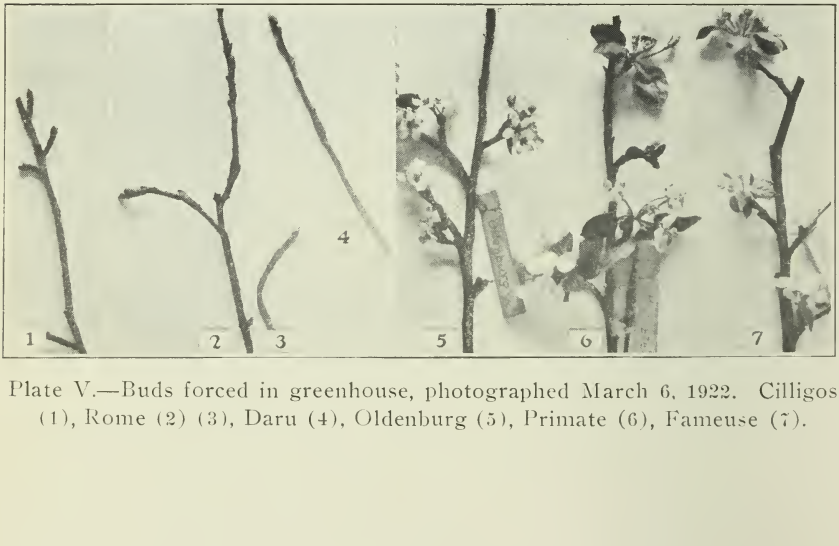

Plate V.—Buds forced in greenhouse, photographed March 6, 1922. Cilligos (1), Rome (2) (3), Daru (4), Oldenburg (5), Primate (6), Fameuse (7).

APPENDIX

Methods.—In the calculations reported in this paper, the date of first blossoming has been used. Though this standard is open to some objections, as, for example, a probable fluctuation with the total quantity of blossoms in the tree, it is less subject to change through varying judgments of different observers than is the date of full bloom.

Several commentators have mentioned the variability in blossoming found in young trees. This may be explained by the fact that often in young trees all the blossoms are on terminal shoots, which open markedly later than blossoms on spurs and if recorded without qualifications may well cause a considerable change in the relative order of blossoming. Phenological records in the apple should distinguish clearly between blossoms on spurs and those on shoots. All samples used in microscopic study were gathered from spurs which had blossomed at least once.

Since progress in phenological studies depends on the availability of data, temperature and phenological records for Columbia, Missouri, are appended.

DATES OF FIRST BLOSSOMING IN APPLE AT COLUMBIA, MO.
(Days of the year)

Variety	1905	1906	1907	1908	1909	1911	1912	1913	1914	1915	1916	1917	1918
Alexander	114	114	94	107	115	109	116	114	113	113	109	--	--
Arkansas	98	111	86	101	108	104	113	108	111	111	106	112	101
Arkansas Beauty	99	110	86	100	108	101	116	109	111	111	108	108	102
Arkansas Black	101	113	88	102	116	107	115	109	111	112	107	111	104
Ashton	97	111	86	102	108	112	118	112	112	112	109	--	--
Autumn Streaked	99	110	--	99	109	106	--	107	112	111	106	109	97
Bailey Sweet	97	110	84	101	107	101	115	107	111	109	105	108	104
Balagh	100	111	86	100	--	103	--	--	112	112	109	113	104
Baldwin	100	111	--	103	114	107	116	110	112	112	109	--	96
Battyani	--	113	93	98	--	103	116	110	112	--	108	--	107
Batullen	98	92	--	98	113	102	116	109	112	112	108	114	101
Ben Davis	99	111	85	101	113	102	115	109	111	111	108	110	102
Ben Hur	--	--	87	104	113	107	116	110	112	110	107	110	96
Black Ben Davis	98	111	--	103	--	101	119	109	112	--	--	--	106
Blenheim	108	114	95	104	116	106	118	112	113	113	--	114	108
Bosnian	105	112	89	103	--	109	--	--	113	--	110	--	105
Brier	95	110	87	99	109	--	--	--	112	112	106	113	96
Canada Reinette	99	111	87	101	109	108	115	112	--	--	--	--	--
Champion	100	110	87	103	--	105	118	110	112	111	109	--	104
Cilligos	117	120	91	113	--	118	115	121	117	116	117	--	--
Clark	99	111	--	101	113	106	116	118	113	--	109	--	--
Clayton	99	111	88	102	112	104	116	110	112	--	108	--	--
Collins	102	110	86	101	109	102	114	109	111	110	107	111	107
Czar Thorn	99	111	85	99	108	104	116	109	--	111	109	109	--
Daru	114	116	105	112	124	112	121	113	107	--	114	--	121
Delaware Red	--	116	88	104	--	-	115	112	115	111	--	--	105
Delicious	--	113	87	104	113	104	116	113	112	111	107	113	102
Devonshire Duke	--	112	87	102	--	106	118	110	116	111	--	113	--
Doctor	101	113	90	101	115	105	115	112	112	111	109	111	106
Downing Blush	--	113	87	102	--	108	118	109	110	--	--	--	--
Eper	115	116	99	103	--	112	--	113	114	113	114	113	108
Fameuse	96	110	86	98	108	104	115	107	109	111	107	108	91

DATES OF FIRST BLOSSOMING IN APPLE AT COLUMBIA, MO.
(Days of the year)

Variety	1905	1906	1907	1908	1909	1911	1912	1913	1914	1915	1916	1917	1918
Faust's Rome Beauty	113	115	99	107	119	105	--	114	113	113	109	--	--
Gano	98	111	86	102	113	103	116	110	111	112	109	114	101
Ginnie	103	111	88	104	114	106	118	110	112	--	108	111	96
Gold Medal	100	114	87	102	113	105	119	111	115	112	109	--	102
Golden Russet	95	120	85	102	--	108	116	--	109	111	106	109	92
Greening	102	111	87	102	116	106	117	111	--	--	--	--	--
Grimes	98	112	87	101	108	106	115	109	110	112	107	111	97
Heidorn	--	115	--	107	116	106	115	111	112	112	112	113	105
Hubbardston	99	111	86	103	114	100	115	112	114	111	108	113	97
Huntsman	101	114	86	100	114	107	115	109	110	113	107	112	101
Imperial Janet	117	117	106	110	--	119	121	119	118	--	115	--	--
Ingram	115	120	104	109	118	118	121	119	119	114	118	128	111
Jeffries	--	--	--	--	--	106	116	110	112	111	107	113	96
Jonathan	97	110	86	102	112	102	116	107	111	110	108	109	97
July	100	112	87	100	--	111	116	111	114	112	109	110	106
Kansas Greening	110	115	108	107	--	111	118	111	112	112	--	--	108
Kartacs	--	116	108	106	118	--	--	115	115	113	110	114	104
King David	--	--	--	--	117	104	115	110	112	111	109	112	103
Lady	116	115	99	108	--	--	--	--	--	111	114	121	--
Lady Carter	99	110	87	101	113	--	--	--	110	--	108	113	102
London	--	115	88	104	112	--	--	--	117	112	109	--	--
Late Duchess	97	109	87	98	107	--	--	--	109	112	106	121	92
Longfield	100	111	95	100	109	--	--	--	115	--	112	--	106
Lou	98	109	87	100	105	--	--	--	--	108	--	108	--
Louise	100	111	86	101	111	--	--	--	112	112	109	112	96
Magyar	105	111	88	103	--	--	--	110	112	112	109	114	106
Maiden Blush	99	110	87	98	108	107	115	108	110	110	107	109	95
Marin	97	110	86	100	109	104	115	107	109	111	105	109	97
Melon	97	110	88	99	108	105	116	108	--	--	--	--	--
Menagera	97	109	86	100	108	101	114	109	108	110	108	109	91
Metitt	100	112	84	102	110	108	115	111	112	111	--	109	96
Miller Boy's Favorite	104	112	87	102	115	109	115	110	110	--	--	--	--
Minkler	98	110	85	99	107	102	119	107	108	109	107	108	96
Minnesota	91	107	85	96	103	100	114	107	108	110	105	108	90
Missing Link	--	--	87	104	110	104	116	108	109	--	107	--	--
Missouri	98	110	85	102	112	103	116	109	111	109	106	112	97
Mosher	110	112	87	104	110	106	118	110	112	112	109	110	--
Mc Intosh	100	111	87	102	109	105	117	110	112	111	109	113	--
Nelson Sweet	100	112	87	103	114	106	116	110	112	113	--	--	--
Noble Savar	99	111	86	100	109	--	118	109	112	112	109	114	--
Nyack	101	114	88	103	115	110	102	111	112	--	--	--	--
Nyari Piros	105	112	86	99	109	104	115	110	109	114	107	--	100
Ohio Beauty	110	113	90	102	--	105	116	111	113	111	111	112	103
Ohio Pippin	99	110	85	100	112	103	116	108	113	111	108	109	97
Oldenburg	94	110	86	98	107	102	114	107	110	--	106	--	97
Olive	99	112	87	102	111	106	--	111	112	113	109	114	--
Ontario	102	113	86	103	117	108	118	112	113	112	--	--	--
Opalescent	--	--	--	106	116	110	117	114	113	111	--	--	107
Payne Keeper	--	--	93	105	114	106	117	113	112	113	109	114	98
Peach	--	118	--	104	--	107	112	112	113	112	110	113	--
Picket	100	110	86	99	110	105	--	--	110	112	109	109	96
Ponyik	104	115	95	105	--	--	118	--	114	113	110	--	106
Primate	97	110	87	99	107	--	114	109	107	110	106	112	90

DATES OF FIRST BLOSSOMING IN APPLE AT COLUMBIA, MO.
(Days of the year)

Variety	1905	1906	1907	1908	1909	1911	1912	1913	1914	1915	1916	1917	1918
Pumpkin Russet	99	111	88	102	117	104	116	112	109	112	--	--	100
Pumpkin Sweet	100	111	87	101	108	--	--	--	110	111	108	110	98
Ralls	113	117	106	110	121	118	121	118	116	114	111	128	117
Reagan	100	112	88	102	111	106	116	--	--	--	--	--	--
Red Astrachan	98	110	88	99	107	102	115	108	109	110	109	--	--
Red June	--	--	--	--	--	104	111	--	112	111	109	113	94
Red Stettiner	99	110	85	100	112	103	116	108	113	111	108	109	97
Rome	105	114	99	107	119	111	115	112	115	114	111	115	108
Rutherford	96	109	85	99	--	--	115	109	112	111	108	110	92
Sabadka	100	115	87	--	--	106	118	112	113	113	109	110	103
Segfu	--	112	87	104	113	110	117	112	112	112	110	110	102
Sekula	104	113	94	102	--	110	--	--	115	--	109	--	102
Selumes	100	112	85	102	107	107	115	114	111	112	108	--	98
Skelton	99	111	87	102	112	--	--	110	114	112	108	--	104
Spitzenberg	99	111	87	102	109	--	--	111	117	--	--	--	--
Standard	93	110	86	99	104	100	--	108	110	112	106	--	92
Stayman	98	110	86	101	112	106	115	110	111	111	109	112	103
Summer Calville	97	110	86	98	108	105	116	109	109	--	108	110	92
Summer King	--	--	--	--	--	--	114	113	--	113	109	112	103
Tetofski	98	110	87	103	108	106	115	109	112	110	106	110	100
Titus Pippin	102	110	86	102	114	106	115	109	111	110	108	111	105
Tudor	99	115	87	--	--	110	116	109	109	--	106	--	98
Wafer	94	112	88	102	113	114	--	110	114	112	110	112	106
Wealthy	--	--	--	104	112	104	117	109	112	111	109	110	103
White Canada	98	112	87	101	109	105	117	108	111	112	108	112	97
White Pippin	97	112	87	102	--	107	116	--	112	--	106	--	94
Wine Rubets	104	112	87	104	117	109	117	110	109	112	109	--	102
Winesap	99	111	87	102	113	104	116	110	112	111	109	109	104
Wolf River	108	113	88	102	112	109	116	110	111	111	110	113	102
Woodmansee	--	--	--	--	--	--	118	113	114	112	110	114	121
Workaroe	109	113	--	103	115	109	118	112	115	111	--	--	--
Yappa	102	112	87	102	116	106	118	108	--	--	--	--	--
Yellow Newtown	--	--	--	104	--	108	117	113	113	112	109	--	103
Yellow Transparent	--	--	--	108	113	104	117	113	113	112	108	110	105
York Imperial	99	113	88	103	113	106	116	111	--	112	--	112	--
York Stripe	103	114	88	104	116	107	117	113	--	--	--	--	--

DAILY MAXIMUM TEMPERATURES, COLUMBIA, MISSOURI
January

	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
1	66	39	40	47	28	46	52	26	56	42	41	62	43	44
2	43	41	49	50	49	29	7	26	38	42	33	42	50	43
3	27	41	47	49	59	23	5	19	42	29	38	48	49	31
4	35	29	46	47	60	29	34	11	36	29	41	61	50	44
5	40	42	65	42	33	25	50	13	23	28	47	63	42	42
6	25	41	72	51	4	12	48	—3	20	39	42	21	56	28
7	24	43	71	52	17	35	55	2	20	54	43	29	40	21
8	32	19	54	44	33	36	47	12	24	58	30	38	54	26
9	31	40	26	52	43	29	47	29	32	40	49	49	57	20
10	10	45	33	47	42	43	68	10	38	28	40	51	52	16
11	32	35	44	36	8	42	67	3	38	44	40	37	22	9
12	15	35	43	30	18	44	31	—5	20	34	41	34	37	0
13	11	43	56	31	32	44	34	20	32	46	52	0	16	15
14	9	48	40	39	35	30	34	22	43	52	54	20	30	18
15	17	58	28	44	34	33	22	7	56	58	61	34	23	16
16	30	37	33	26	30	37	27	29	60	53	58	11	22	23
17	39	57	34	40	27	51	28	43	59	43	28	18	30	18
18	40	40	54	43	36	44	29	33	38	50	31	23	30	13
19	37	63	60	49	37	57	41	20	64	66	34	32	40	17
20	46	72	26	58	46	44	54	27	35	47	25	55	40	16
21	34	65	49	58	61	32	39	48	32	32	20	57	60	20
22	24	17	39	44	74	42	33	49	37	54	19	52	17	24
23	33	24	35	35	72	50	45	51	42	60	14	54	36	37
24	31	43	51	32	65	44	49	34	41	41	16	62	34	42
25	10	47	23	47	40	62	55	39	54	38	26	60	45	42
26	30	48	18	42	43	61	71	50	53	62	31	63	41	28
27	37	48	25	42	57	41	60	35	43	64	26	56	42	15
28	29	47	32	42	61	42	47	34	43	65	15	33	66	18
30	25	48	33	31	10	29	40	28	54	30	42	31	51	19
31	27	46	35	34	18	32	64	41	31	43	51	27	47	5

DAILY MAXIMUM TEMPERATURES, COLUMBIA, MISSOURI

February

	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
1	15	44	37	17	43	57	81	33	14	52	48	16	6	11
2	—2	27	36	31	55	51	38	21	26	55	32	17	3	30
3	5	55	14	35	63	38	54	20	32	38	38	21	36	24
4	20	42	11	37	65	43	41	18	30	32	56	36	38	11
5	20	14	12	52	60	44	46	17	15	35	37	36	24	53
6	21	21	21	36	45	31	43	23	27	32	31	22	48	50
7	23	30	25	49	43	40	41	24	25	15	34	14	47	59
8	28	40	47	41	54	41	46	22	34	16	38	35	38	65
9	29	27	50	43	53	32	40	20	35	45	45	41	24	40
10	13	29	41	46	33	43	47	34	40	37	65	44	29	63
11	27	43	49	46	56	42	48	39	36	28	64	44	21	65
12	9	58	57	62	54	25	54	30	21	21	69	35	33	54
13	—1	51	60	54	35	42	64	37	38	22	61	21	44	59
14	24	28	43	40	36	59	54	36	52	24	49	33	35	62
15	15	28	60	38	21	63	78	41	51	38	34	43	38	30
16	30	37	60	34	25	17	76	53	61	27	51	56	56	32
17	30	36	62	39	49	17	65	53	63	54	57	52	52	36
18	35	55	66	37	46	30	39	55	69	42	55	40	33	51
19	35	61	44	23	38	39	32	45	63	27	51	55	52	60
20	34	59	43	37	54	41	26	35	38	30	54	55	33	16
21	44	57	25	34	58	26	22	30	51	48	52	59	53	19
22	47	69	26	56	54	26	31	40	34	38	50	63	64	45
23	55	54	31	49	55	10	35	52	23	17	47	37	56	69
24	51	50	35	49	35	28	43	43	26	21	34	49	37	65
25	50	45	50	48	55	43	48	39	40	32	41	43	68	63
26	60	39	54	36	56	42	39	35	40	46	35	37	62	51
27	44	32	58	31	52	33	34	38	29	53	35	32	31	42
28	63	50	61	52	65	48	29	33	22	50	40	31	41	38
29	----	----	----	71	----	----	----	27	----	----	----	38	----	----

DAILY MAXIMUM TEMPERATURES, COLUMBIA, MISSOURI
March

	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
1	59	62	54	48	67	57	34	31	28	27	44	32	36	50
2	67	59	59	48	70	70	46	24	31	39	42	32	34	58
3	76	34	54	45	49	76	59	29	49	35	42	26	31	51
4	58	33	40	49	48	76	46	33	41	43	31	50	22	62
5	67	34	51	74	62	81	70	27	38	50	33	53	38	76
6	39	40	41	71	54	64	59	37	30	40	29	66	57	42
7	44	42	49	46	62	58	49	36	52	34	34	43	50	53
8	50	60	45	40	46	57	63	33	67	37	39	38	50	65
9	53	52	38	47	42	42	71	28	57	47	41	56	64	73
10	43	39	39	56	43	48	61	31	55	48	39	52	69	47
11	43	32	53	50	39	60	82	35	59	34	37	49	54	65
12	50	22	55	73	46	61	60	36	61	47	41	76	44	77
13	47	29	37	55	51	69	49	40	57	62	45	76	54	90
14	69	25	43	74	37	47	60	37	54	69	49	51	45	61
15	70	25	63	66	45	52	50	33	28	79	39	36	54	50
16	71	23	66	66	48	65	45	51	39	55	46	52	60	56
17	66	26	68	63	52	67	64	58	63	53	44	56	41	73
18	71	29	67	63	72	71	52	65	68	36	42	62	41	76
19	55	30	80	45	48	74	60	67	68	30	42	54	65	72
20	36	34	70	51	48	70	72	41	50	37	33	71	49	74
21	48	46	92	61	50	73	77	28	34	37	37	86	64	80
22	73	32	90	60	60	90	59	32	45	46	37	64	71	62
23	61	29	82	67	69	88	53	34	72	58	47	54	64	42
24	71	35	77	67	66	85	58	39	53	68	63	82	66	59
25	71	55	90	81	45	82	71	48	39	70	50	69	75	69
26	71	59	82	73	67	86	61	49	33	73	39	56	59	75
27	82	42	82	78	49	86	50	42	32	61	48	51	50	64
28	69	39	78	44	55	86	66	43	53	77	53	63	69	61
29	60	37	58	57	45	78	55	59	62	67	46	62	62	66
30	73	53	61	48	52	65	46	68	75	58	44	68	82	72
31	77	49	47	67	49	60	45	72	63	69	40	59	80	75

DAILY MAXIMUM TEMPERATURES, COLUMBIA, MISSOURI

April

	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
1	81	55	54	57	57	71	48	50	72	57	40	52	50	79
2	72	70	63	38	56	69	69	57	79	63	46	50	54	83
3	70	74	63	60	61	74	43	65	72	46	54	61	62	51
4	58	61	70	65	85	76	47	74	50	52	71	59	54	55
5	55	56	50	65	84	56	55	80	65	60	75	56	54	54
6	55	64	50	80	76	60	63	72	69	56	76	45	59	58
7	61	73	57	69	59	73	49	55	53	46	75	36	51	60
8	86	69	47	70	48	77	57	66	46	36	77	44	46	53
9	90	72	52	54	51	75	58	67	65	46	70	50	57	48
10	74	66	51	63	59	81	62	68	48	53	69	68	70	54
11	59	78	54	59	73	63	54	77	44	49	63	82	70	53
12	62	82	47	69	61	58	78	76	43	57	58	84	57	52
13	64	66	45	79	55	72	66	74	57	62	60	70	51	64
14	53	45	52	68	64	71	53	74	68	65	71	59	59	66
15	48	54	62	68	65	68	62	65	72	72	77	68	52	61
16	46	63	45	57	80	47	70	49	77	83	81	62	73	73
17	55	69	51	61	87	42	77	44	84	83	79	65	83	65
18	61	74	44	64	78	40	61	55	79	70	76	79	83	67
19	66	77	47	81	48	42	62	53	66	51	84	76	80	55
20	75	75	56	83	51	66	61	70	63	64	78	70	62	38
21	61	81	60	80	55	78	61	73	81	84	76	55	72	50
22	64	64	65	82	54	65	58	58	82	81	78	67	81	63
23	70	61	70	79	60	40	59	68	80	67	86	65	86	63
24	73	87	78	73	69	36	60	75	60	81	84	61	81	48
25	73	80	72	75	71	42	63	65	60	81	84	57	61	45
26	59	82	57	55	82	59	75	72	64	86	78	51	53	58
27	80	86	65	48	64	77	58	67	57	81	83	61	49	58
28	85	70	81	54	80	85	76	66	66	71	85	69	54	62
29	72	77	72	52	88	91	82	57	73	58	73	73	49	55
30	73	61	47	57	51	80	72	67	84	53	73	64	54	56

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

RESEARCH BULLETIN 54

Studies In Animal Nutrition

II. Changes in Proportions of Carcass and Offal on Different Planes of Nutrition

(Publication authorized September 1, 1922.)

COLUMBIA, MISSOURI

SEPTEMBER, 1922

UNIVERSITY OF MISSOURI

COLLEGE OF AGRICULTURE

Agricultural Experiment Station

STUDIES IN ANIMAL NUTRITION

II. Changes in Proportions of Carcass and Offal on Different Planes of Nutrition.

C. Robert Moulton, P. F. Trowbridge,* L. D. Haigh

The changes experienced by beef cattle in form and weight when on different planes of nutrition were presented and discussed in a previous bulletin†. Representative animals from each of the groups were killed at intervals from birth to four years old. The data collected in the slaughter house will be presented in this bulletin.

RATION

For a general discussion of the treatment of the animals the previous bulletin must be consulted. The ration included milk for several months after birth and timothy hay and grain were soon introduced. At weaning time the ration consisted of alfalfa hay and a grain mixture in the ratio of one to two. The grain consisted of six parts corn chop, three parts whole oats, and one part of old process linseed meal.

PLANE OF NUTRITION

The animals were early divided into three groups. Group I was fed all it would eat of the ration. Group II was fed for maximum growth without permitting the laying on of much fat. Group III was fed for scanty or retarded growth. The Group II steers gained about a pound a day for the first two years while the Group III cattle gained but 0.69 pounds per day.

SLAUGHTERING

In the conduct of this experiment great care was exercised that all of the operations with the different animals should be carried out under similar conditions. Although the slaughtering and subsequent operations were necessarily carried out at different times,

*Resigned September, 1918.

†C. Robert Moulton, P. F. Trowbridge, L. D. Haigh, Studies in Animal Nutrition, I. Changes in Form and Weight on Different Planes of Nutrition. Mo. Agr. Expt. Station, Research Bulletin 43.

in order to make the results strictly comparable the slaughtering and cutting were done by the same experts each time*.

Each animal was slaughtered on the day following the closing of its feeding period. In the morning the steer was fed and weighed as usual but no water was given. If slaughter occurred late in the morning or in the afternoon the animal was weighed again immediately before slaughtering. The animal was led from the feeding shed to the slaughter house followed by men with a shovel and long handled dipper to catch any feces or urine that might be voided.

The animal was stunned with a knocking hammer, shackled by the hind legs and hoisted to swing clear of the floor. An oil cloth, funnel shaped bag had been fastened to the muzzel before hoisting so that any vomit voided could be caught and weighed. The suspended animal was stuck in the throat near the brisket so that both the jugular vein and carotid artery were severed. Complete bleeding was assured by pumping the fore legs up and down. The blood was caught in a tared pan and weighed. The volume of this main weighed portion was determined. A tared pan was kept under the animal to catch any blood that might drip while skinning out the head.

While the blood was flowing freely the samples for analysis were taken and poured in suitable quantity into tared, covered containers and crucibles. The blood was still warm and no clotting had yet occurred.

While the carcass was hanging the head was skinned out. The gullet was firmly tied with a skewer thrust through below the tie and the head was then severed permitting the dripping blood to collect in a tared container. The head was immediately placed in a large can provided with a cover and the weight obtained. The tongue with larynx and bones was removed, separated into tongue marketable, tongue base, bones, larynx, and piece of gullet. The parts were weighed and set aside in closed containers. Horns were sawed off and weighed. The skull and entire head was split accurately in half and the brain was removed and weighed. The lean meat and fat were removed from the right half as were the teeth. If any vomit was found it was weighed and discarded. Both halves of the head were weighed. The total lean and fat were obtained

*Swift & Company of Kansas City furnished an expert butcher to do the slaughtering. Mr. Samuel Godfrey, foreman of the beef cutting department, did the cutting.

by doubling the right-side weights and the total bone by subtracting the sum of the lean and fat from the sum of the two halves of the head minus the teeth.

As soon as the suspended carcass with the head removed had practically stopped bleeding it was lowered to the floor with the anterior end lying up the slope of the smooth cement floor. A man with a rubber window wiper and sharp edged dust pan kept all oozing blood wiped up and transferred to weighed containers.

In skinning out the feet the dew claws were removed, weighed and saved and care was taken to remove the hide exactly at the hoof line. From the right feet the hoofs were separated and the remainder of the material was considered as skeleton. The usual packing house order of procedure was followed in skinning the carcass and removing the internal organs. The caul fat was removed while the carcass was on its back. The bladder was tied before removing and weighed with its contents and again empty. The rectum was tied as soon as it was cut loose. The tail was removed and split in two and the lean and fat meat separated and weighed.

The contents of the abdominal and thoracic cavities was caught in a large tub, or tubs, and weighed. The separation and weighing of the organs was pushed as rapidly as possible to reduce to a minimum the loss of water by evaporation. A double tie was made at the end of the small intestine near the abomasum before severing one from the other. The fat was carefully cut or scraped from all four stomachs and weighed. The intestines were also carefully freed from fat, and this was generally accomplished without any portion becoming smeared with the contents. The stomachs were emptied of the contents and were cleaned by washing with water after which they were wiped dry with cloths. The contents of the intestines were removed by stripping through the fingers taking a section at a time. The stripped sections were split open and the inside was wiped lightly to remove all contents. Occasionally it was necessary to wash and wipe a smeared portion. The various organs were separated, weighed and put into closed containers.

The hide was removed and the carcass was split into halves. Then the spinal cord was removed. The diaphragm was removed back to the striated muscle and composited with the internal organs.

The carcass was allowed to chill for 48 hours and the right

side was separated into the two quarters and then into the standard wholesale cuts. (Figure 1). Each cut was separated into lean meat, fatty tissue and bone. The tendons were weighed with the bone. In the separation of the lean and fat, care was taken that the fatty tissue should contain no lean meat. Necessarily the lean meat contained small pieces of fat which could not be separated. The meat was cut from the bones as completely as could be done with a boning knife. All samples were kept in closed tin containers.

The further treatment of the separated parts is of interest only in connection with the chemical analysis and the description will be deferred to a later publication.

THE SLAUGHTER HOUSE DATA

The detailed slaughter house data obtained are given in the Appendix in Tables 1 to 5 for the offal parts and Tables 6 to 10 for the carcass parts. Few of the weights need explanation. The warm empty weight was obtained by subtracting the contents of the stomachs, intestines, and urinary bladder and any excrement voided before death from the live weight at slaughtering. The heart and neck sweetbreads are the thymus gland. The stomach and intestinal fats are those which adhered to the respective organs. The intestinal fat is largely included in the mesentery. The caul fat is that laid on in the part of the peritoneum stretching like an apron over the stomachs and intestines. The different divisions are mutually exclusive excepting where specified otherwise.

TABLE I.—PERCENT EMPTY WEIGHT TO LIVE WEIGHT.

Age	Group I	Group II	Group III
At birth	98.41	98.41	98.41
3 months	88.02	89.27	83.89
5½ months	84.32	85.29	86.63
8½ months	83.16	82.28	83.19
11 months	88.30	87.61	87.10
18 months	88.77	....	90.37
21-26 months	90.44	88.69	87.05
34 months	90.39	91.63	....
38 months stunted ..	92.30	....	....
40 months	93.26	89.19	88.95
45 months	90.40	87.68	89.01
47-48 months	92.24	90.12	89.09

Empty Weight.—Table I gives the proportion of empty weight in the live animal from birth to four years for each group of cattle. The figures in this table as well as in Tables II to XVIII inclusive

are taken from Tables 11 to 15 in the Appendix. The figures presented for the animal at birth are for the average of Hereford calves reported in Research Bulletin 38 of this Station. The complement of the percent of empty weight is of course the percent of fill.

The animal at birth has the largest percent of empty weight. This is due to the lack of food and food residues in the alimentary canal. The figure decreases during the early months showing a large proportion of fill and is least at 8½ months. It then gradually increases with some irregularity and becomes at about 3 years and thereafter a higher proportion than at any time since birth.

The amount of the ration affects the percent of the empty weight. The lighter rations show generally a smaller percent of empty weight and consequently indicate more relative fill. Since the weight of the ration is smaller and the weight of fill is smaller this can only be due to a greater difference in weight of animal resulting in a decreased percent of empty weight. At 8½ months there is practically no difference between the three groups.

Carcass.—Tables II and III show the percent of carcass in the live and empty animals respectively. The percent of carcass to live weight decreases to about 8½ months and then increases to reach at 3 to 4 years a higher value than at any previous time. For the first six months there is little difference between the groups but thereafter the better fed animals have the greater percent of carcass.

The effect of varying proportions of fill is shown in the figures discussed in the above paragraph. On the empty weight basis there is a continuous increase in percent of carcass from birth to

TABLE II.—PERCENT CARCASS TO LIVE WEIGHT.

Age	Group I	Group II	Group III
At birth	59.30	59.30	59.30
3 months	54.19	57.32	53.63
5½ months	53.71	53.00	54.39
8½ months	54.17	50.46	51.09
11 months	57.52	53.85	55.23
18 months	60.46	....	56.02
21-26 months	58.24	57.71	54.27
34 months	61.49	60.49	....
38 months stunted	65.69	....	....
40 months	70.42	61.18	58.08
45 months	65.32	60.28	60.34
47-48 months	68.95	61.80	59.63

TABLE III.—PERCENT CARCASS TO EMPTY WEIGHT.

Age	Group I	Group II	Group III
At birth	60.39	60.39	60.39
3 months	61.56	64.21	63.92
5½ months	63.70	62.14	62.78
8½ months	65.14	61.33	61.41
11 months	65.14	61.47	63.41
18 months	68.11	....	61.98
21-26 months	64.39	65.07	62.34
34 months	68.03	66.02	....
38 months stunted	71.17	....	....
40 months	75.52	68.59	65.29
45 months	72.25	68.76	67.80
47-48 months	74.75	68.58	66.63

3 or 4 years of age. The relation between the groups is the same as when the live weight formed the basis.

Carcass and Offal Fat.—In Tables IV and V are shown the percents of carcass plus offal fat to live and empty weights. The offal fat is the hand separable fat on the internal organs. It is small in amount in the young animals, being entirely negligible in the calf at birth. In the very fat four year old steer it amounts to nearly five percent of the animal. The effect of adding this fat to the carcass weight is merely to increase the spread of the figures with increasing age and fatness. The general relations pointed out in the section above hold here.

TABLE IV.—PERCENT CARCASS AND OFFAL FAT TO LIVE WEIGHT.

Age	Group I	Group II	Group III
At birth	59.30	59.30	59.30
3 months	55.45	58.06	54.17
5½ months	57.01	54.53	54.23
8½ months	56.05	52.23	51.85
11 months	61.16	56.17	56.69
18 months	65.04	....	57.40
21-26 months	63.01	59.79	55.89
34 months	65.51	62.96	....
38 months stunted ..	71.34	....	....
40 months	76.18	63.58	59.46
45 months	71.62	62.53	62.60
47-48 months	73.33	64.98	62.19

TABLE V.—PERCENT CARCASS AND OFFAL FAT TO EMPTY WEIGHT.

Age	Group I	Group II	Group III
At birth	60.39	60.39	60.39
3 months	62.99	65.03	64.57
5½ months	67.61	63.94	63.76
8½ months	67.40	63.48	62.33
11 months	69.26	64.12	65.08
18 months	73.27	....	63.49
21-26 months	69.67	67.41	64.21
34 months	72.47	68.71	....
38 months stunted ..	77.30	....	....
40 months	81.69	71.29	66.84
45 months	79.22	71.32	70.33
47-48 months	79.49	72.11	69.80

TABLE VI.—PERCENT OFFAL FAT TO EMPTY WEIGHT.

Age	Group I	Group II	Group III
At birth	none	none	none
3 months	1.43	0.83	0.65
5½ months	3.91	1.80	0.98
8½ months	2.26	2.16	0.92
11 months	4.12	2.65	1.68
18 months	5.16	....	1.51
21-26 months	5.28	2.34	1.87
34 months	4.45	2.70	....
38 months stunted ..	6.13	....	....
40 months	6.17	2.70	1.55
46 months	6.97	2.56	2.54
47-48 months	4.74	3.53	3.17

Table VI gives the percent of offal fat to the empty animal. There is a rather consistent increase in percent of offal fat with increasing age and fatness. A striking exception is shown by the four year old Group I steer. This is due to a great decrease in the

Fig. 1.—Wholesale divisions of the beef carcass.

weight of offal fat, this animal having but 38.5 kilograms while the next younger animals had 53.6 and 48.3 kilograms respectively. The low figure should be taken with reservations as to its general applicability.

Hide and Hair.—The percent of hide and hair referred to empty weight is given in Table VII. There are some variations due to individuality but in general the percent decreases from birth to four years. The percent also decreases with increasing plane of nutrition. Put in different language the percent of hide and hair decreases with increasing age and fatness of the animal.

Blood.—In Table VIII are presented the figures for the percent of blood referred to empty weight. The maximum is at three months. At birth it is less and as age increases beyond three months it becomes less. In the poorer fed groups the percent of blood becomes fairly constant, however, while in the full fed group it continues to decrease with age. In the early stages the full fed animals have as much or more than the others but as the age increases the Group I steers have a materially smaller percent of blood.

TABLE VII.—PERCENT HIDE AND HAIR TO EMPTY WEIGHT.

Age	Group I	Group II	Group III
At birth	12.13	12.13	12.13
3 months	10.51	9.48	9.26
5½ months	8.16	10.60	9.27
8½ months	8.53	8.62	9.04
11 months	8.81	9.72	9.44
18 months	7.40	....	8.69
21-26 months	8.65	9.80	10.47
34 months	7.43	8.23	....
38 months stunted ..	7.15	....	....
40 months	5.88	8.35	9.34
45 months	5.87	8.90	9.61
47-48 months	6.15	8.36	8.81

TABLE VIII.—PERCENT BLOOD TO EMPTY WEIGHT.

Age	Group I	Group II	Group III
At birth	4.93	4.93	4.93
3 months	6.24	5.35	6.37
5½ months	5.18	5.25	5.35
8½ months	5.08	5.85	5.19
11 months	4.33	4.54	5.06
18 months	4.09	....	4.93
21-26 months	4.41	4.53	5.13
34 months	4.16	4.85	....
38 months stunted ..	3.61	....	....
40 months	3.48	4.43	5.28
45 months	3.33	4.44	4.67
47-48 months	3.52	4.90	5.22

For a somewhat different presentation of these and other figures bearing on the relation of blood, surface, and nitrogen to the animal the reader is referred to two earlier publications from this Station[1]

Heart.—The percent of the heart referred to the empty weight

[1]P. F. Trowbridge, C. R. Moulton, L. D. Haigh, The Maintenance Requirement of Cattle, Research Bulletin 18, Missouri Agr. Expt. Station (1915).

C. R. Moulton, Units of Reference for Basal Metabolism and Their Interrelations, Jour. Biol. Chem. XXIV. 299-320 (1916).

is given in Table IX. The figures are not notable but are very small and decrease with increasing age and fatness. There is, however, very little difference between Groups II and III.

Lungs.—The proportion of lungs and trachea to the empty weight (Table X) increases during the first few months of life and then falls rather steadily with advancing age. The well fed group has materially less lungs than the other groups especially at the older ages.

Central Nervous System.—The percent of brain and spinal cord is given in Table XI. There is a rather steady and uniform decrease with increasing age and fatness. From slightly less than 0.9 percent at birth it decreases to 0.09 percent at maturity for the fattest animal.

Stomachs.—In contrast to the foregoing organs and parts the stomachs (Table XII) show an increasing proportion from birth to 8½ months for Groups I and II and from birth to two years for

TABLE IX.—PERCENT HEART TO EMPTY WEIGHT.

Age	Group I	Group II	Group III
At birth	0.55	0.55	0.55
3 months	0.53	0.43	0.44
5½ months	0.54	0.57	0.50
8½ months	0.45	0.46	0.56
11 months	0.38	0.54	0.49
18 months	0.45	....	0.53
21-26 months	0.34	0.44	0.44
34 months	0.40	0.49	....
38 months stunted	0.32	....	....
40 months	0.41	0.39	0.49
45 months	0.30	0.44	0.42
47-48 months	0.27	0.40	0.36

TABLE X.—PERCENT LUNGS TO EMPTY WEIGHT.

Age	Group I	Group II	Group III
At birth	1.01	1.01	1.01
3 months	1.30	1.16	1.32
5½ months	1.14	1.10	1.26
8½ months	1.09	1.21	1.23
11 months	0.87	1.12	1.09
18 months	0.84	....	1.00
21-26 months	0.76	1.00	0.62
34 months	0.54	0.90	....
38 months stunted	0.67	....	....
40 months	0.55	0.89	1.07
45 months	0.63	0.83	0.84
47-48 months	0.47	0.79	0.92

TABLE XI.—PERCENT BRAIN AND CORD TO EMPTY WEIGHT.

Age	Group I	Group II	Group III
At birth	0.86	0.86	0.86
3 months	0.41	0.51	0.50
5½ months	0.32	0.47	0.61
8½ months	0.27	0.37	0.58
11 months	0.20	0.29	0.37
18 months	0.14	....	0.30
21-26 months	0.15	0.24	0.27
34 months	0.11	0.18	....
38 months stunted	0.11	....	....
40 months	0.09	0.15	0.24
45 months	0.10	0.18	0.19
47-48 months	0.09	0.14	0.20

TABLE XII.—PERCENT STOMACHS TO EMPTY WEIGHT.

Age	Group I	Group II	Group III
At birth	0.99	0.99	0.99
3 months	2.01	1.55	1.88
5½ months	2.51	1.95	2.19
8½ months	3.03	3.17	2.83
11 months	2.73	2.85	2.83
18 months	2.37	....	2.78
21-26 months	2.69	2.77	3.33
34 months	1.96	2.30	....
38 months stunted	1.90	....	....
40 months	1.32	2.57	2.51
45 months	1.74	2.44	2.52
47-48 months	1.74	2.25	2.70

Group III. The proportion then becomes less and continues to fall for the full fed group. In the early months the full fed group has the greater percent of stomachs but in later years the smaller percent of stomachs.

These figures show a retarded development of the stomachs for the group receiving the lightest ration. All groups show a decrease in percent with advancing maturity.

Intestines.—The intestines (Table XIII), however, show a much less marked increase in percent with the early months and a much less marked retarding of development with Group III. After the first few months the percent of intestines decreases with increasing age and fatness.

The above evidence may be affected by the thickness or diameter of the intestines. The relative length is given in Table XIV. It is seen that at birth the beef animal has much the greatest length of intestines per unit of empty weight and that this proportion decreases continuously with advancing age. After three months the proportion decreases with increased plane of nutrition and consequent size and fatness of the animal.

Table XIII.—Percent Intestines to Empty Weight.

Age	Group I	Group II	Group III
At birth	2.60	2.60	2.60
3 months	2.75	2.66	3.44
5½ months	2.37	2.80	2.93
8½ months	2.61	2.99	2.91
11 months	1.79	2.15	2.37
18 months	1.29	....	1.92
21-26 months	2.00	1.55	2.24
34 months	1.02	1.34	....
38 months stunted	0.83	....	....
40 months	0.64	0.97	1.24
45 months	0.76	0.93	0.99
47-48 months	0.60	1.08	1.11

Table XIV.—Cm. of Intestines per Kg. of Empty Weight.

Age	Group I	Group II	Group III
At birth	45.24	45.24	45.24
3 months	34.83	37.17	34.61
5½ months	22.03	31.41	39.03
8½ months	20.78	27.87	34.43
11 months	15.17	25.19	23.83
18 months	11.69	....	19.21
21-26 months	10.88	13.80	....
34 months	6.99	9.46	....
38 months stunted	6.05	....	....
40 months	6.28	10.37	11.35
45 months	7.18	10.16	10.62
47-48 months	5.95	11.23	10.62

At birth there are 45 centimeters per kilogram of empty weight while the oldest fattest steer shows less than six.

Liver.—The liver is a most important chemical laboratory of the body. Its proportion should be affected by the amount of the ration perhaps more than by the size of the animal. The figures given in Table XV show a rather steady decrease from birth to four years in Group II and Group III. Group I, however, shows an increase up to 8½ months and then a decrease with increasing age.

From birth up to about two years old the Group I cattle show relatively more liver than do the other groups. Thereafter this group shows less but not more than one-third less than the Group III animals. The highest figure is 1.84 percent and the lowest 0.73 percent.

TABLE XV.—PERCENT LIVER TO EMPTY WEIGHT.

Age	Group I	Group II	Group III
At birth	1.76	1.76	1.76
3 months	1.79	1.49	1.75
5½ months	1.84	1.19	1.28
8½ months	1.66	1.65	1.50
11 months	1.39	1.25	1.16
18 months	1.24	....	1.15
21-26 months	1.00	0.97	1.08
34 months	0.89	0.90	....
38 months stunted	0.84	....	....
40 months	0.73	0.83	0.94
45 months	0.77	0.84	0.99
47-48 months	0.76	0.89	1.14

TABLE XVI.—PERCENT KIDNEYS TO EMPTY WEIGHT.

Age	Group I	Group II	Group III
At birth	0.32	0.32	0.32
3 months	0.34	0.68	0.62
5½ months	0.38	0.32	0.41
8½ months	0.26	0.31	0.35
11 months	0.22	0.31	0.26
18 months	0.19	....	0.26
21-26 months	0.18	0.21	0.25
34 months	0.16	0.18	....
38 months stunted	0.16	....	....
40 months	0.16	0.22	0.24
45 months	0.13	0.19	0.20
47-48 months	0.13	0.22	0.25

Kidneys.—The kidneys (Table XVI) show for Group I cattle much the same changes as are shown by the liver. There is an increase from birth to 5½ months and then a steady decrease. Groups II and III show a very striking increase in proportion of kidneys at three months where the figure is double that shown at birth. Thereafter there is a decrease to two years of age when the figures become about constant.

The percent of kidneys is smaller the higher the plane of nutrition and the bigger and fatter the animal. This is especially true after the age of one year.

Spleen.—The percent of spleen to empty weight is given in Table XVII. It increases at first with increasing age and then remains quite constant for Groups II and III. For Group I it decreases from three months until 38 to 40 months when it becomes constant.

During the early months the Group I cattle show as much, or more, spleen as do the other groups. Thereafter the proportion decreases with increased plane of nutrition.

Pancreas.—The figures for the pancreas are presented in Table XVIII. In discussing these it must be remembered that this organ becomes embedded in fat as the animal grows fatter and even appears to have large areas of fat scattered through it. The person

making the separation has increasing difficulty in separating the organ from the fat or, in fact, in telling whether he has obtained the organ at all.

Table XVII.—Percent Spleen to Empty Weight.

Age	Group I	Group II	Group III
At birth	0.19	0.19	0.19
3 months	0.31	0.26	0.24
5½ months	0.28	0.29	0.25
8½ months	0.23	0.24	0.22
11 months	0.21	0.21	0.24
18 months	0.19	....	0.25
21-26 months	0.28	0.25	0.21
34 months	0.22	0.27	....
38 months stunted .	0.17	....	....
40 months	0.16	0.19	0.24
45 months	0.14	0.21	0.33
47-48 months	0.15	0.25	0.26

Table XVIII.—Percent Pancreas to Empty Weight.

Age	Group I	Group II	Group III
At birth	0.08	0.08	0.08
3 months	0.10	0.10	0.15
5½ months	0.13	0.10	0.10
8½ months	0.12	0.17	0.17
11 months	0.12	0.13	0.13
18 months	0.13	....	0.16
21-26 months	0.06	0.09	0.06
34 months	0.06	0.06	....
38 months stunted .	0.13	....	....
40 months	0.11	0.12	0.14
45 months	0.11	0.13	0.14
47-48 months	0.10	0.15	0.15

With these reservations in mind it may be said that the proportion of pancreas increases with increasing age until 8½ months is reached. The percent then becomes somewhat less or at least no greater. There is but little difference between the groups. The smaller proportion shown after 40 months may or may not be fact owing to the difficulties stated.

Main Divisions of Animal.—Figure 2 shows the growth of certain tissues and parts of the animals of all three groups from birth to four years. A general idea of the weight and proportion of the skeleton, lean flesh, fatty tissue, organs, hide, and remainder can be obtained from a study of the figure.

Figures 3 to 5 show the percent of the various parts enumerated above referred to the empty animal.

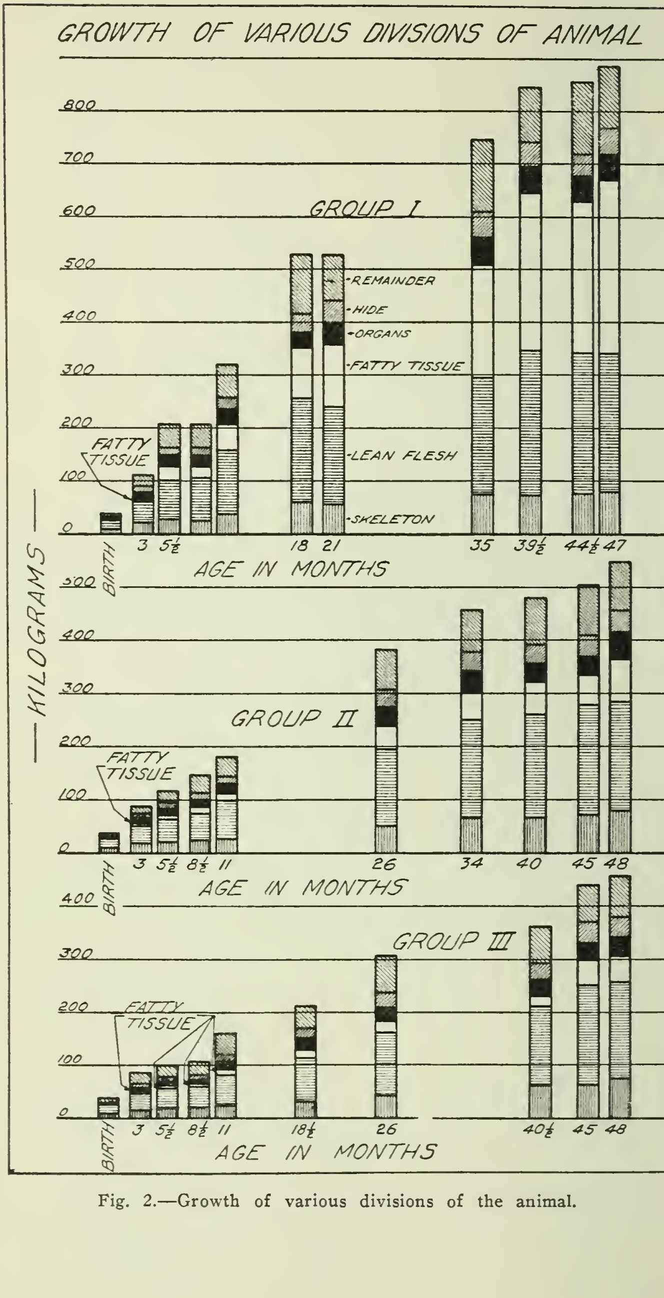

Fig. 2.—Growth of various divisions of the animal.

In Group I (Figure 3) the skeleton decreases from 28 percent at birth to 10 percent at four years. The lean flesh is more constant, increasing from 39 percent at birth to 44.5 percent at 8½ months while the mature steer has but 32 percent. The fatty tissue

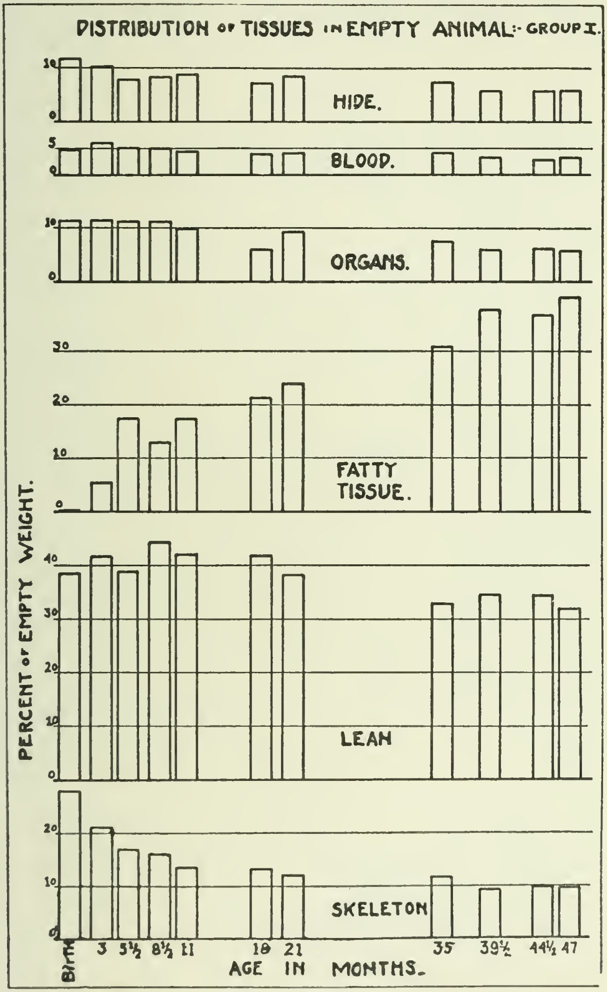

Fig. 3.—Distribution of tissues in empty animal—Group I.

increases very markedly from an amount so small as to be inseparable from the lean at birth to 40 percent at four years. The organs of the animal are about 11 percent from birth to 8½ months. They then decrease to about 6 percent at four years. The blood and the hide have been discussed above.

In Group II (Figure 4) less change with advancing age is shown. This is largely due to a smaller amount of fatty tissue being formed. The skeleton decreases from about 28 percent at birth to 16 percent at four years. The lean flesh is about 39 percent at birth and increases to 46 percent at 45 months. The four year old

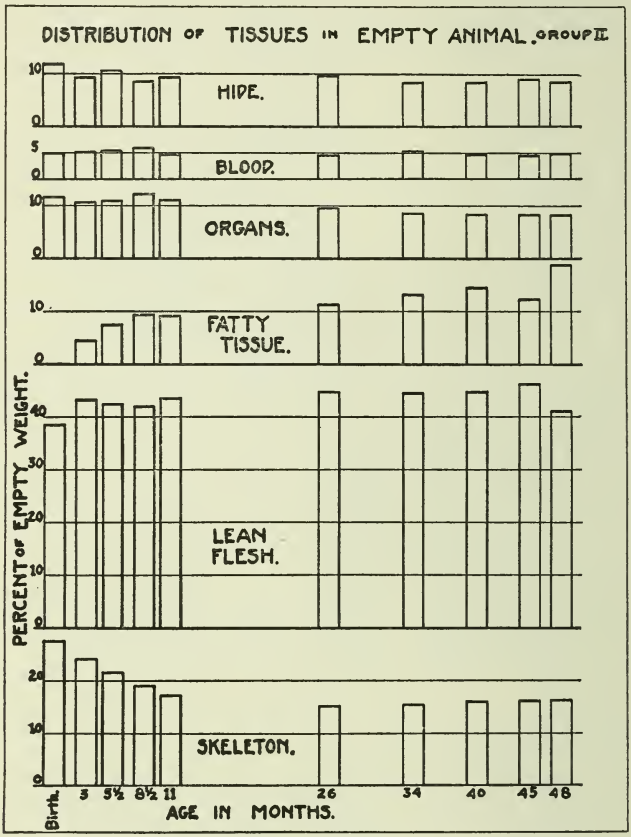

Fig. 4.—Distribution of tissues in empty animal—Group II.

steer shows but 41 percent, probably an abnormal figure due to an increase in percent of fatty tissue. The fatty tissue increases from practically nothing to 19 percent at four years. The organs are about 11 percent at birth and 8.5 percent at four years.

Group III (Figure 5) shows still less change. The skeleton decreases from about 28 percent at birth to 18 percent at four years. The lean flesh increases from 39 percent at birth to 45 to 48 percent at the end. The fatty tissue is small in amount running from practically nothing at birth to only a little over 11 percent at four years. The organs decrease from 11 percent at birth to 9 percent at four years.

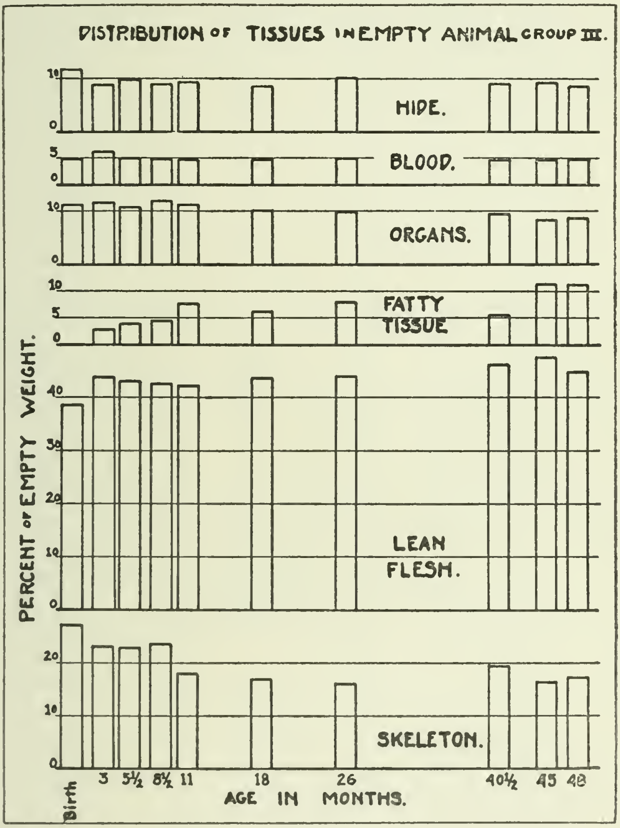

Fig. 5.—Distribution of tissues in empty animal—Group III.

Loss on Cooling and Cutting.—The weights and percents of the main divisions of the empty animal and the calculated loss on cooling and cutting are given in the appendix in Tables 16 to 20. The losses vary from practically nothing to over 6 percent in the case of one animal. Five animals show about 5 percent. The other

25 animals show less than 3 percent loss. This loss is largely moisture lost from the animal during slaughter, cooling, and cutting. While the differences between the groups are not large, in general the greater percent losses are from the thin animals. The covering of fat on the Group I steers protects the carcass and even the offal from as great a moisture loss.

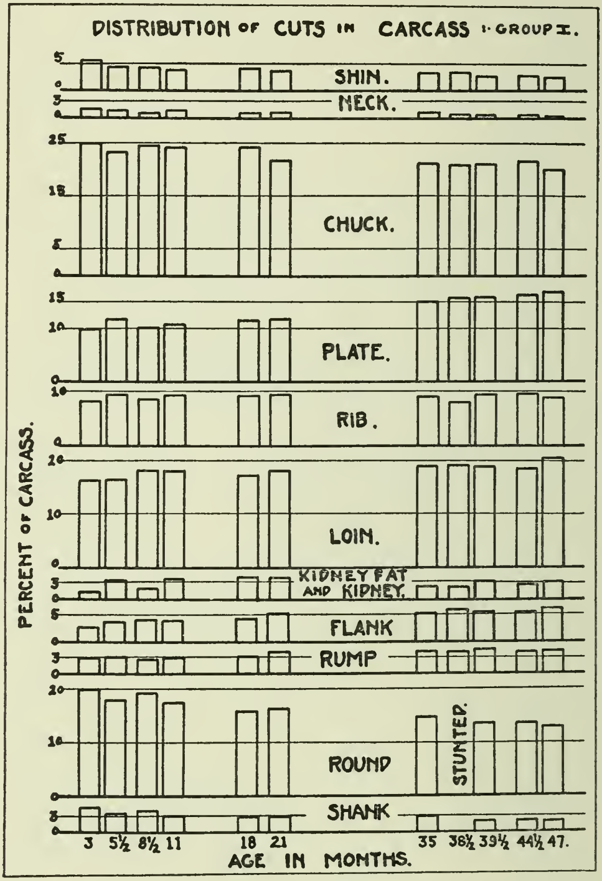

Fig. 6.—Distribution of cuts in carsass—Group I.

DISTRIBUTION OF WHOLESALE CUTS

Tables 21 to 25 in the appendix give the detailed figures for the distribution of the wholesale cuts in the carcass. Figures 6 to 8 show these figures graphically.

In Group I (Figure 6) the shank (hind shank) decreases from about 5 percent at three months to 2 percent at four years. The

round decreases from 20 percent to 13 percent. The rump increases from 3 to a little over 4 percent. The flank increases from 3 to 6 percent. The kidney fat increases from about 1 percent at three months to 4 percent in the baby beef (18 to 21 months) and then decreases again to 2 to 3 percent. The loin increases from 16.5 percent to 21 percent at four years. The rib cut does not vary

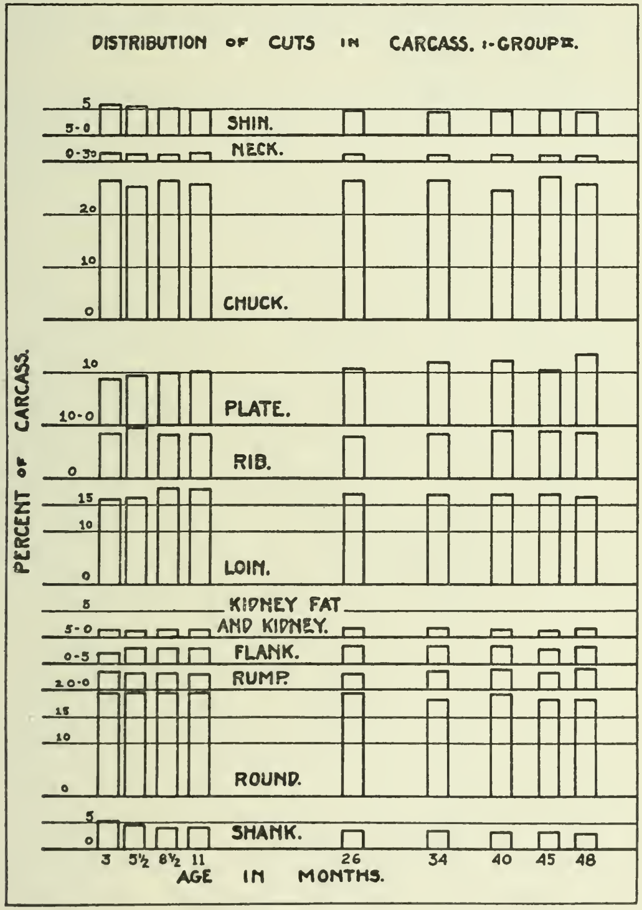

Fig. 7.—Distribution of cuts in carcass—Group II.

much being 8 percent at three months, and 9 to 10 percent at four years. The plate increases from 10 percent to 17 percent. The chuck decreases from 25 percent to 20 percent. The neck decreases from about 2 percent to 1 percent and the shin (fore shank) decreases from 6 percent to 3 percent.

The Group II cattle show much less marked changes in distribution of the cuts from three months to four years. The shank decreases from 5 to 3 percent, the round from 20 to 18 percent, the shin from 6 to 4 percent, and the neck from nearly 2 to 1 percent. The flank increases from 2 to 4 percent, the loin increases from 16 to 18 percent at 8½ months and then decreases again to less than 17 percent, and the plate increases from less than 9 percent to nearly 14 percent. The rump, kidney and kidney fat, rib, and chuck remain fairly constant.

In Group III (Figure 8) there is less change with age. The shank, kidney and kidney fat, and shin decrease with age. The loin and plate show fair increases while the rump and flank show slight increases. The round, rib, chuck, and neck show individual variations but on the whole are constant.

The fatter animal, then, increases its proportion of loin, the most expensive cut, of rump, a less expensive cut, and of flank and plate very cheap cuts. The rib cut, a rather expensive cut, increases but slightly. On the average for all three groups it is constant. The round, a valuable cut, decreases with increasing fatness as do the chuck and the neck. The shin and shank decrease in all cases with increasing age irrespective of fattening. Summing up the changes with respect to the effect of fattening on the three expensive cuts—loin, rib, and round—it is seen that the first increases with fattening, the second remains fairly constant, and the third decreases.

LEAN, FAT, AND BONE IN THE CARCASS

Figure 9 (Tables 26 to 30 in the appendix) shows the proportions of skeleton, lean flesh and fatty tissue in the entire carcasses of the steers from three months to four years for all three groups.

In the Group I steers the skeleton decreases from about 25 percent to 10 percent, and the lean flesh decreases from 67 percent to 42 percent. The fatty tissue of the carcass, on the other hand, increases from 6 percent to nearly 48 percent.

In Group II the changes are not so marked since relatively less fattening occurs. The skeleton decreases from nearly 28 percent to a little over 18 percent and the lean flesh decreases from 66 percent at three months and 68 percent at 11 and 26 months to 58 percent at four years. The fatty tissue increases from 5 percent to 22 percent.

The changes are still less marked in Group III. The skeleton decreases from 27 percent to a little over 20 percent while the lean flesh increases from 67 percent at three months to about 70 percent

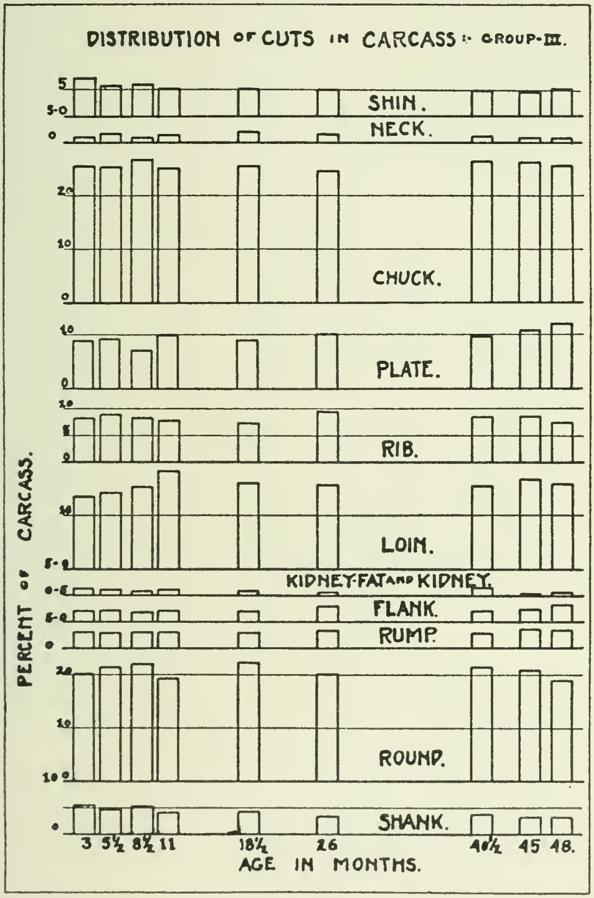

Fig. 8.—Distribution of cuts in carcass—Group III.

from 18½ months on to 45 months. The four-year-old steer shows a decrease to a little over 66 percent. The fatty tissue increases from a little over 3 percent to over 12 percent.

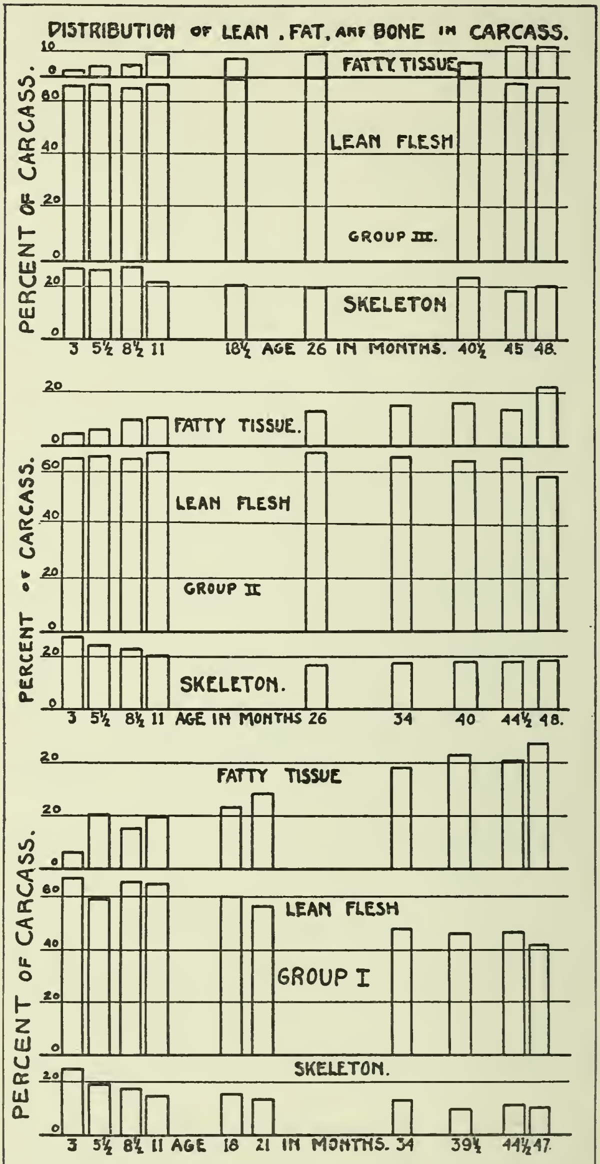

Fig. 9.—Distribution of lean, fat, and bone in carcass.

DISTRIBUTION OF THE TOTAL LEAN FLESH

Figures 10 to 12 (Tables 31 to 35 in the Appendix) show the distribution of the total lean flesh of the animal among the wholesale cuts.

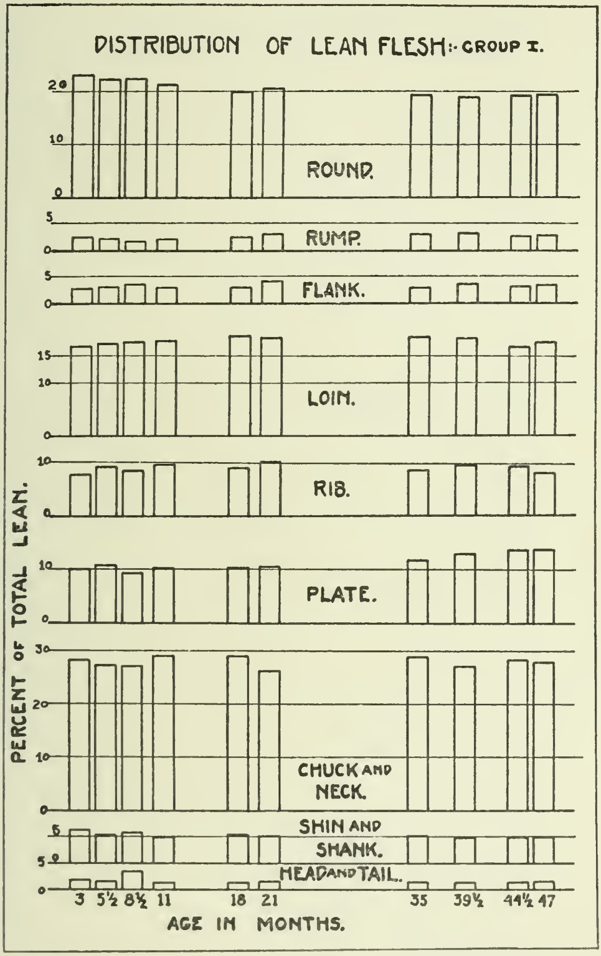

Fig. 10.—Distribution of lean in cuts of carcass—Group I.

In Group I the head and tail contain about 2 to 3 percent of the total lean. The shin and shank together have 5 to 6 percent. The chuck and neck combined have 26 to 29 percent. The plate has 10 to 14 percent, the rib 8 to 10 percent, the loin 17 to 19 percent, the flank 3 to 4 percent, the rump 2 to 3 percent, and the round 23 to 19.5 percent. The shin and shank, the head and tail,

and the round contain a smaller part of the total lean with advancing age and fatness of this group. The chuck and neck, rib, loin, flank, and rump show but little effect of age and fatness. The plate, on the other hand, shows an appreciable relative increase with advancing age and fatness.

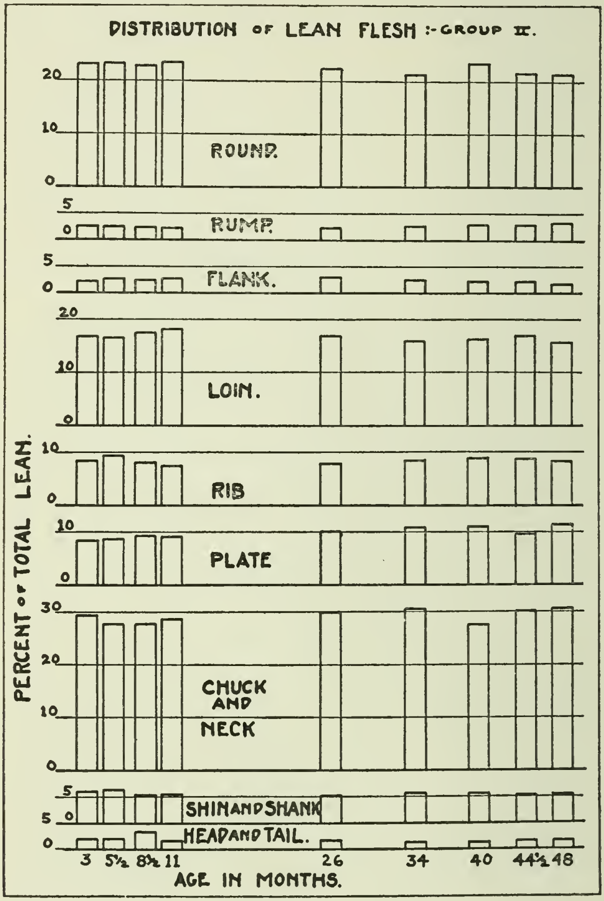

Fig. 11.—Distribution of lean in cuts of carcass—Group II.

In Group II (Figure 11) the head and tail, shin and shank, rib, flank, and rump have about the same percent of the total lean as shown by Group I. The chuck and neck and the round contain relatively more in the Group II steers, while the plate and loin contain relatively less. The differences are, however, not very great in any case being generally within 2 percent. The plate shows

an increase with increasing age while the round shows a decrease. The other cuts show little effect of age.

With the Group III animals (Figure 12) the head and tail, shin and shank, flank, and rump have about the same proportion of total lean as shown by the other groups. The head and tail in

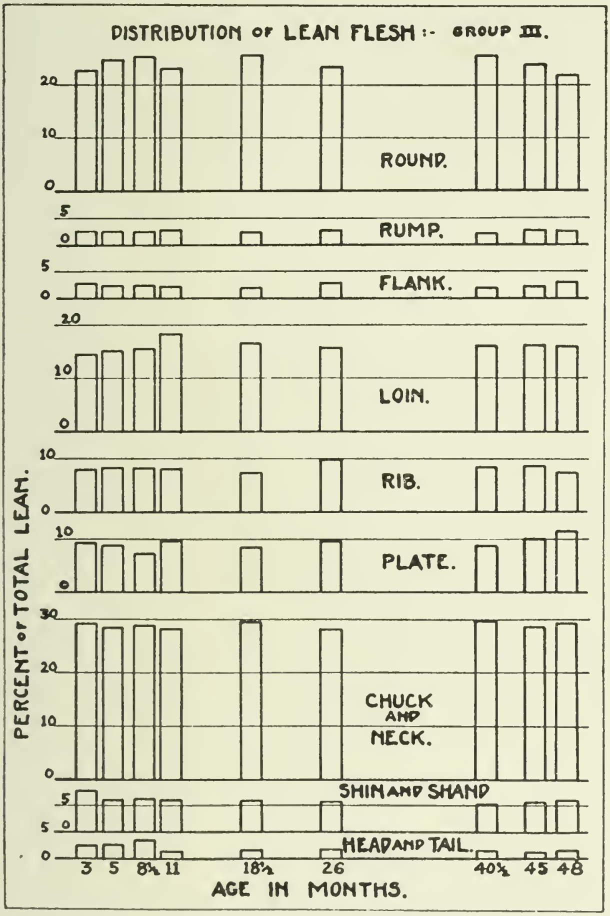

Fig. 12.—Distribution of lean in cuts of carcass—Group III.

some cases runs 1 percent higher and the shin and shank 2 percent higher. The plate, rib, loin, and round vary over wider limits while the chuck and neck keep within narrower limits. The round varies from 20 to 26 percent, the loin from 14.5 to 19 percent, the plate from 7 to 12 percent, and the rib from 7 to 10 percent. There seems to be no consistent effect of age excepting a reduction of the head and tail and the shin and shank.

DISTRIBUTION OF TOTAL FAT FLESH

The distribution of the total fatty tissue exclusive of the offal fat is shown in Figures 13 to 15 (Tables 36 to 40 in the Appendix). There is much greater variation, and age and fatness affect the distribution of fatty tissue quite markedly.

In Group I (Figure 13) the head and tail contains 3 to 4 percent of the fatty tissue in the young animal and less than 0.5 percent in the four-year-old steer. The shin and shank start with about 6 percent and have less than 2 percent at four years. The chuck and neck have about 19 percent at three months and 13 to 15 percent at four years. The plate increases from 7.5 percent to 21 percent, and the rib increases from 2 to 10 percent. The kidney fat increases from 10 percent at three months to 16 percent in the baby beef (11 to 18 months) and drops again to 6 or 7 percent in the old animals. The loin increases its proportion from 20 percent to 25 percent. The flank decreases from 11 to 9 percent and the round decreases markedly from 17 to about 7 percent. The rump increases slightly from 3.5 to 5 or 6 percent. With increasing age and fatness, therefore, a greater part of the fatty tissue is found in the plate, rib, loin, and rump and a smaller part in the head and tail, shin and shank, chuck and neck, flank, and round. The kidney fat at first increases and then decreases.

In Group II (Figure 14) the head and tail have 5 to 6 percent of the total fat in the young animal and only 1 percent in the old animal. The shin and shank decrease from 8 to 2 percent. The chuck and neck starts at about 18 percent. It then rises to 21 percent at 11 months and falls to about 13 percent at 34 months. It then rises again to 21 percent at 44½ months and decreases to 15 percent at four years. The plate increases its proportion of fat from 9 to 20 percent with advancing age. The rib has none of the total fat at three months and 13 percent at four years. The kidney fat is 9 to 10 percent of the total from three months to 34 months with the exception of the 11-month-old steer which has but 5.5 percent. From 40 months on there is but 6 percent of the total here. The loin, like the chuck and neck, shows two maxima. It increases from 16 percent at three months to 26 percent at 8½ months. It then decreases to 21 percent. At 34 to 40 months it is 23 percent, only to decrease to less than 21 percent at four years. The flank in general shows a decrease in the proportion of total fat found here. The variations in the rump are not a function of

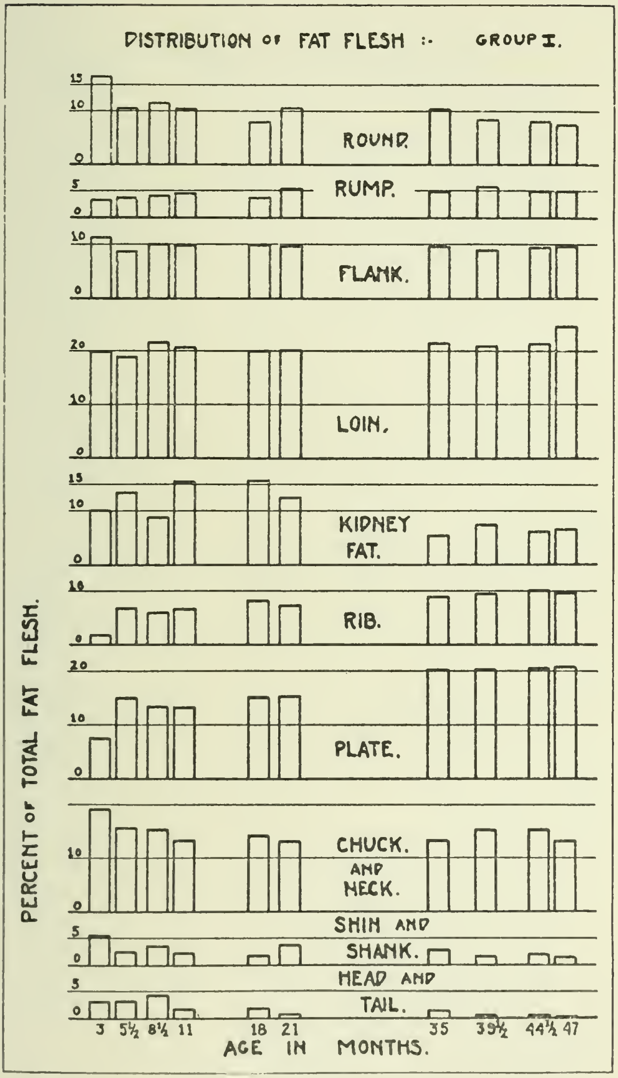

Fig. 13.—Distribution of fat in cuts of carcass—Group I.

age, while the round decreases from 19 percent to 10 percent at 40 months and then increases again to 13 percent. With increasing fatness, then, a greater part of the total fatty tissue is found in the plate and rib. This is true in general of the loin, although

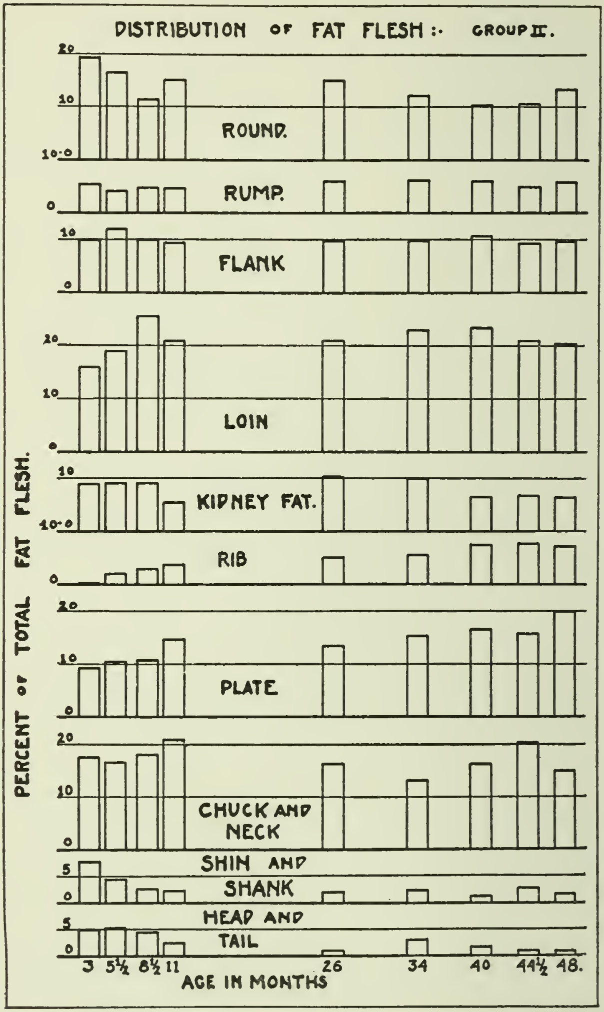

Fig. 14.—Distribution of fat in cuts of carcass—Group II.

there are cycles which have higher maxima at younger ages. The chuck and neck show cycles also but have less at the end. The rump and flank show little change with age, while the head and tail, shin and shank, and round decrease.

Group III (Figure 15) shows greater individual variations than do the other groups. Practically every wholesale cut shows irregu-

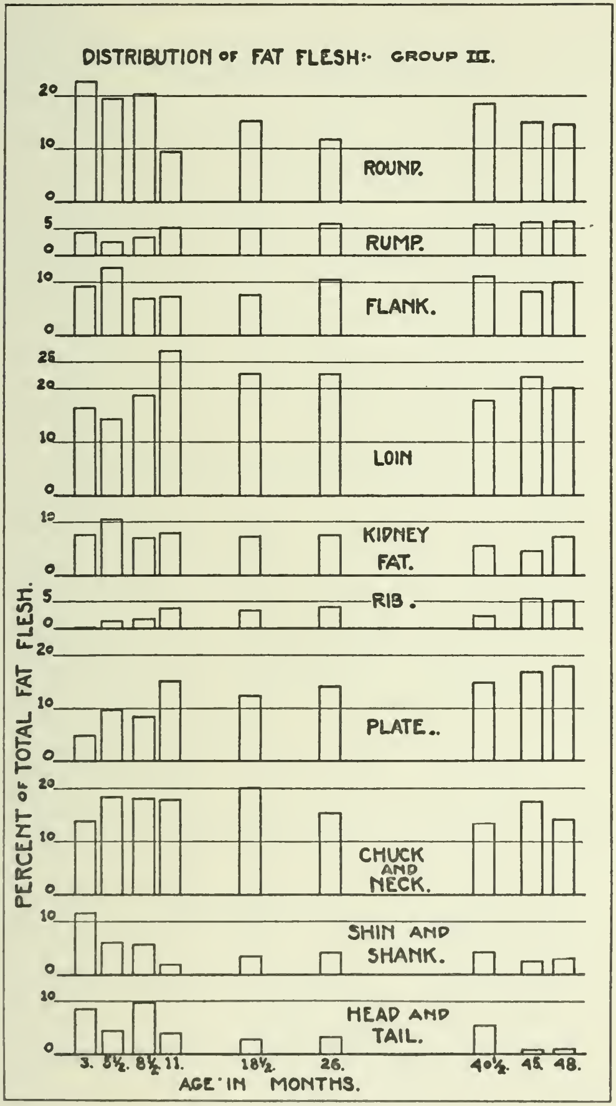

Fig. 15.—Distribution of fat in cuts of carcass—Group III.

lar changes. The head and tail and the shin and shank decrease rather uniformly while the plate and rib increase uniformly. The round has less at four years than at three months while the loin

has more, but there are many ups and downs in between. The changes in the other cuts do not consistently follow age.

DISTRIBUTION OF TOTAL SKELETON

Figures 16 to 18 (Tables 41 to 45 in the Appendix) show the changes in the distribution of the total skeleton for the three groups

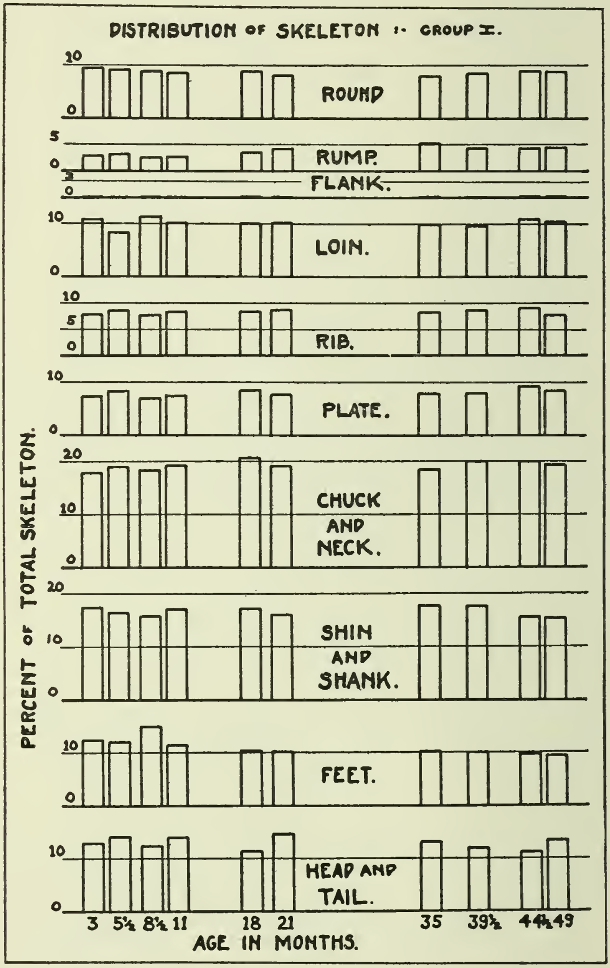

Fig. 16.—Distribution of bone in cuts of carcass—Group I.

with advancing age. The values are much more constant than for either the lean flesh or the fatty tissue.

In Group I (Figure 16) the head and tail have about 13 percent

of the total skeleton with variations from about 11.5 to 14.5. The feet bones increase from about 12.5 percent at three months to 15 percent at 8½ months and then decrease to 9.5 percent at four years. The shin and shank decrease rather uniformly from 17.5

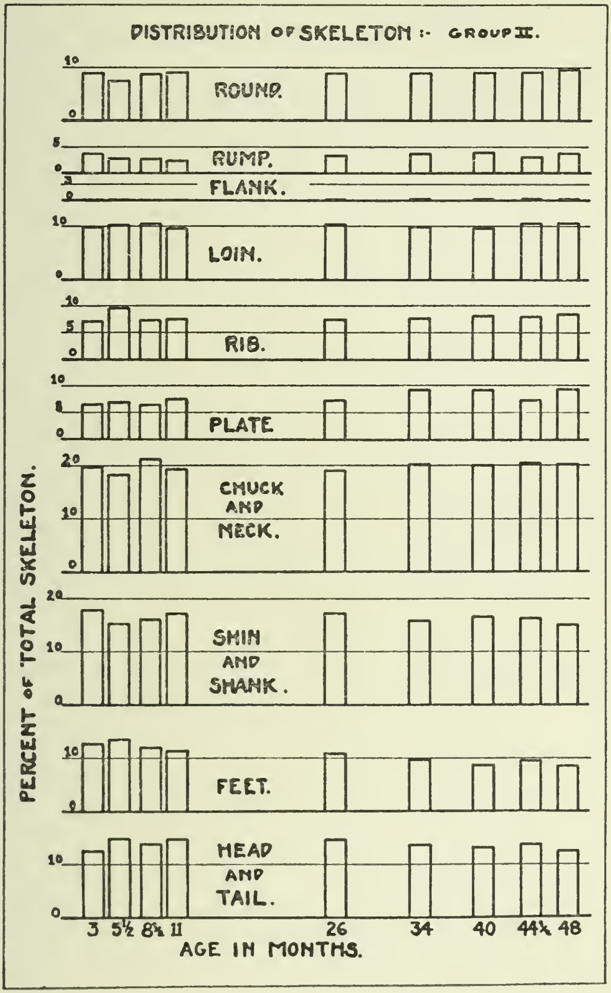

Fig. 17.—Distribution of bone in cuts of carcass—Group II.

to 15.5 percent. The chuck and neck bones increase from 18 to 21 percent at 18 months and then decrease to 19.5 percent. The plate bones vary from 7.5 to 9 percent increasing slightly with age. The rib varies around 8 percent and the loin around 11 percent. The flank has but a tip of rib bone in it and varies from a few hun-

dredths of a percent to about 0.2 percent increasing with age. The rump increases slightly from 3 to 5 percent, while the round decreases very slightly from 9.5 to 9 percent.

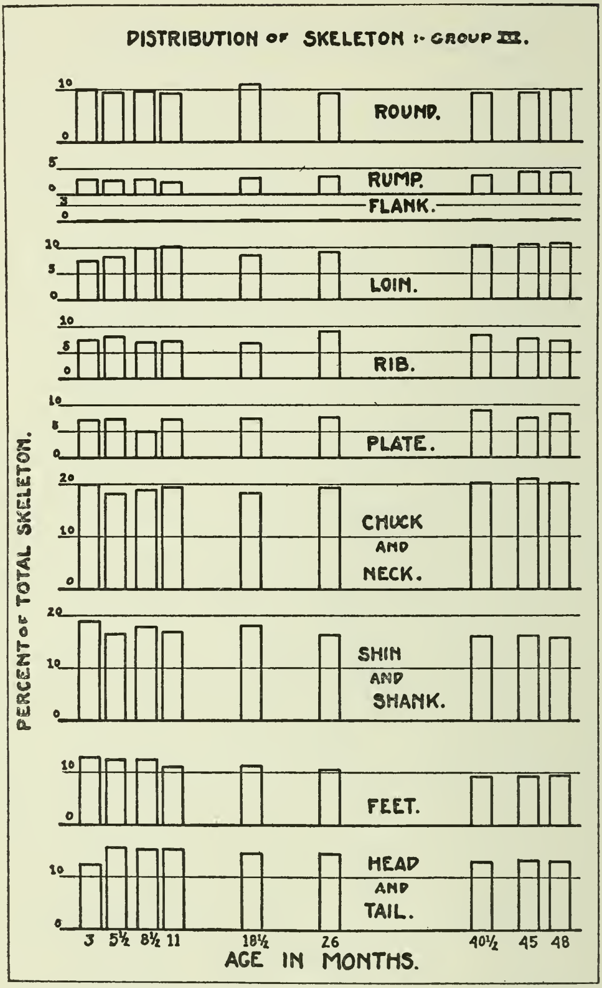

Fig. 18.—Distribution of bone in cuts of carcass—Group III.

Groups II and III (Figures 17 and 18) show somewhat greater variations but the range of the figures is much the same. The increase in the proportion of skeleton found in the feet at 8½ months is not seen. In other respects the figures are much as those for Group I.

DISTRIBUTION OF LEAN, FAT, AND BONE IN THE WHOLESALE CUTS

The Shin (Fore Shank).—With the Group I animals (Figure 19) the lean forms about 50 percent of the shin, the fat 5 to 18 percent and the bone 48 to 34 percent. The percent of fat increases with age and fatness and the bone decreases, while the lean varies.

With the Group II animals the lean forms 44 to 53 percent of the cut, the fat 3 to 6 percent, and the bone 50 to 40 percent. The lean increases with age while the bone decreases. The fat changes but little with age.

With the thinnest animals—Group III—the lean is 46 to 57 percent of the cut, the fat 3 to 5 percent, and the bone 50 to 40 percent. There are more irregularities shown in this group, but in general the lean increases in percent with age while the bone decreases.

The Neck.—The neck of the Group I animals (Figure 20) contains from 66 to 40 percent lean, 12 to 33 percent fat, and 18 to 30 percent bone. The fat increases with increasing age and fatness while the lean decreases. The bone varies between the limits given without respect to age. The amount and composition of this cut will depend much upon the general conformation and fatness of the carcass. There will then be considerable differences between individuals.

In the Group II animals the neck is 50 to 67 percent lean, 4 to 14 percent fat, and 23 to 39 percent bone. The percent of lean, of fat, or of bone, does not seem to depend on age.

The Group III animals show even greater variations and no better correlation between age and composition.

The Chuck.—The chuck (Figure 21) of the Group I animals has 72 to 58 percent lean, 4 to 30 percent fat and 23 to 12 percent bone. The lean and bone decrease with age while the fat increases.

With the Group II animals the lean is 70 to 75 percent of the cut, the fat 3 to 12 percent and the bone 26 to 17 percent. The fat increases with age, the bone decreases, and the lean is about constant.

In the case of the Group III animals the lean runs 70 to 75 percent, the fat 2 to 8 percent and the bone 24 to 19 percent. The fat increases slightly with age, the bone decreases slightly while the lean is fairly constant.

The Plate.—The plate (Figure 22) becomes rather a fat cut

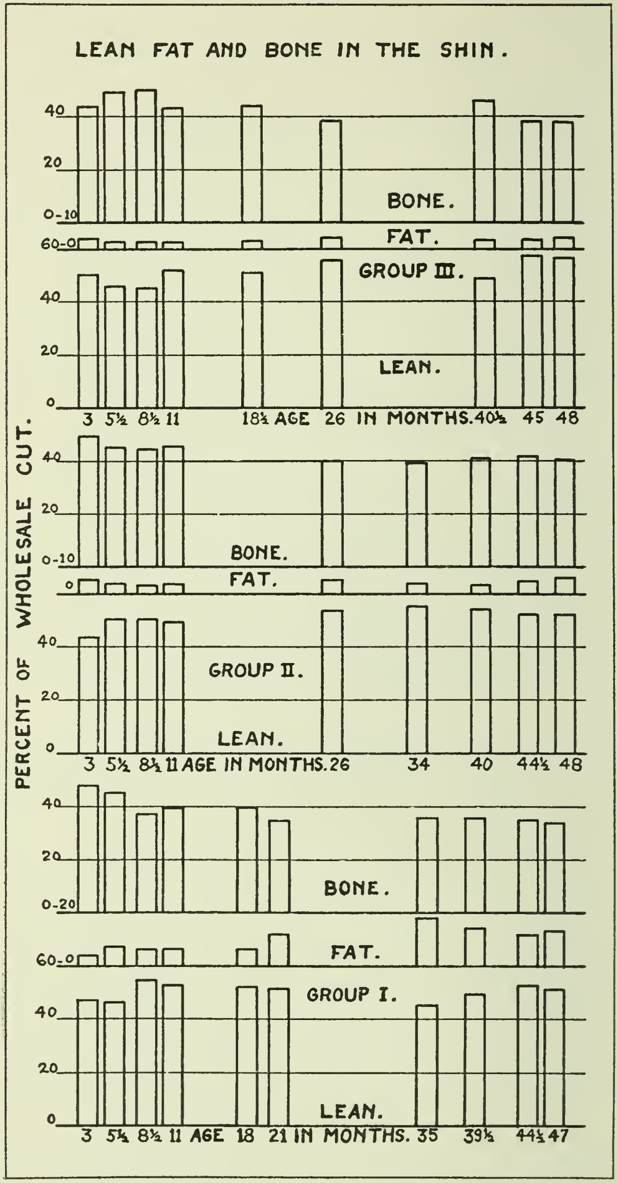

Fig. 19.—Distribution of lean, fat and bone in the shin.

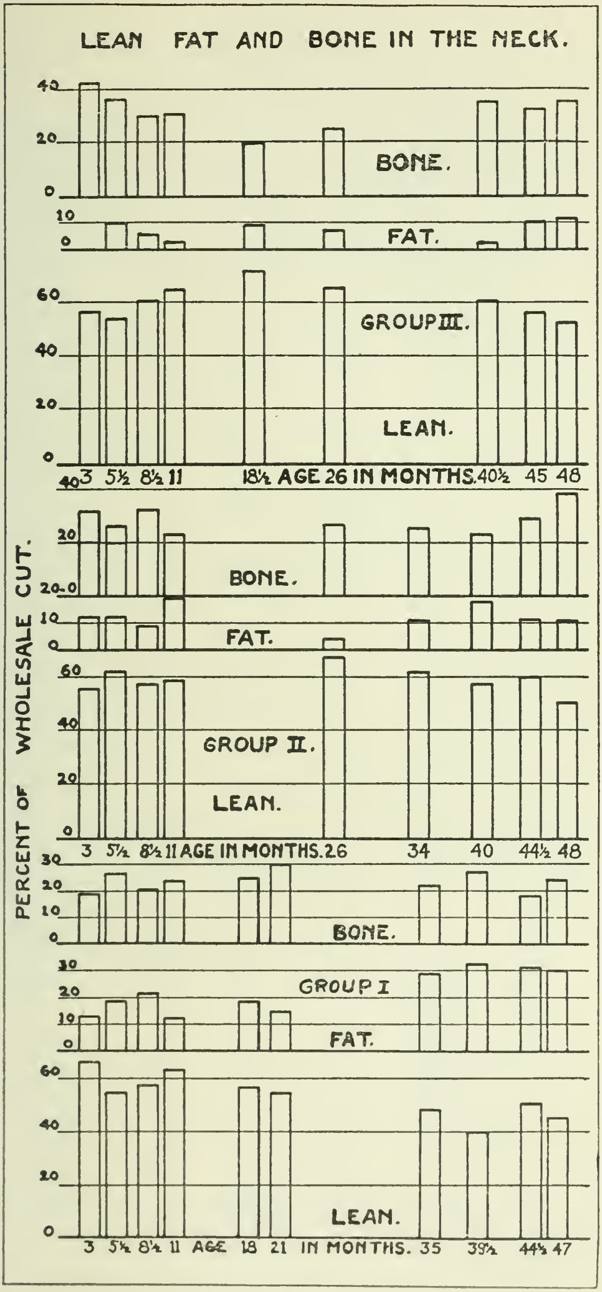

Fig. 20.—Distribution of lean, fat and bone in the neck.

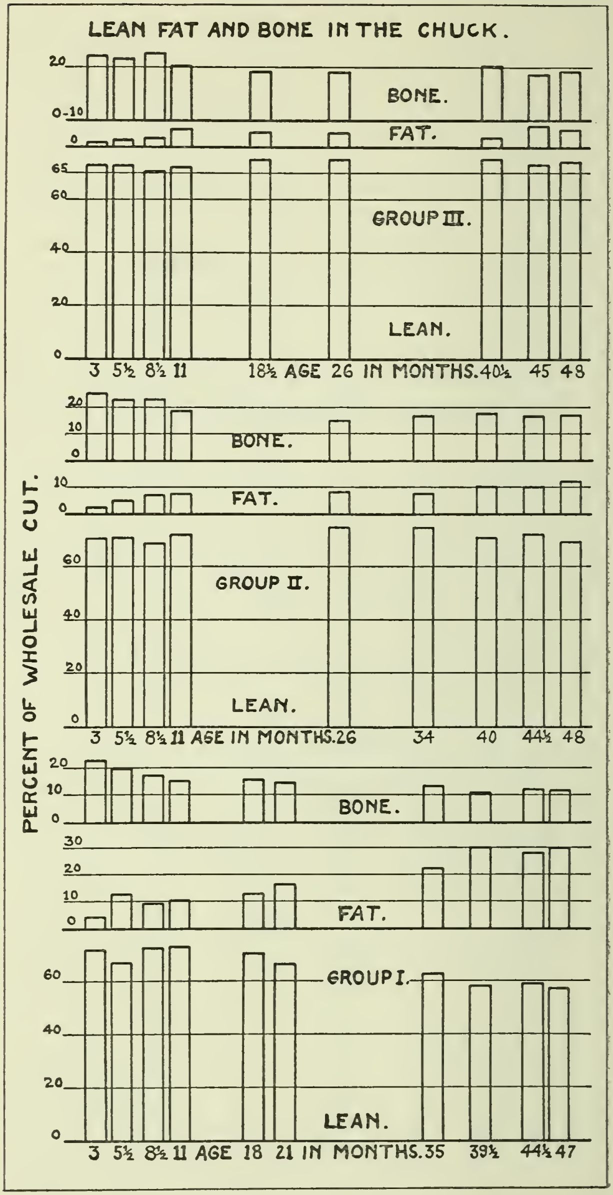

Fig. 21.—Distribution of lean, fat and bone in the chuck.

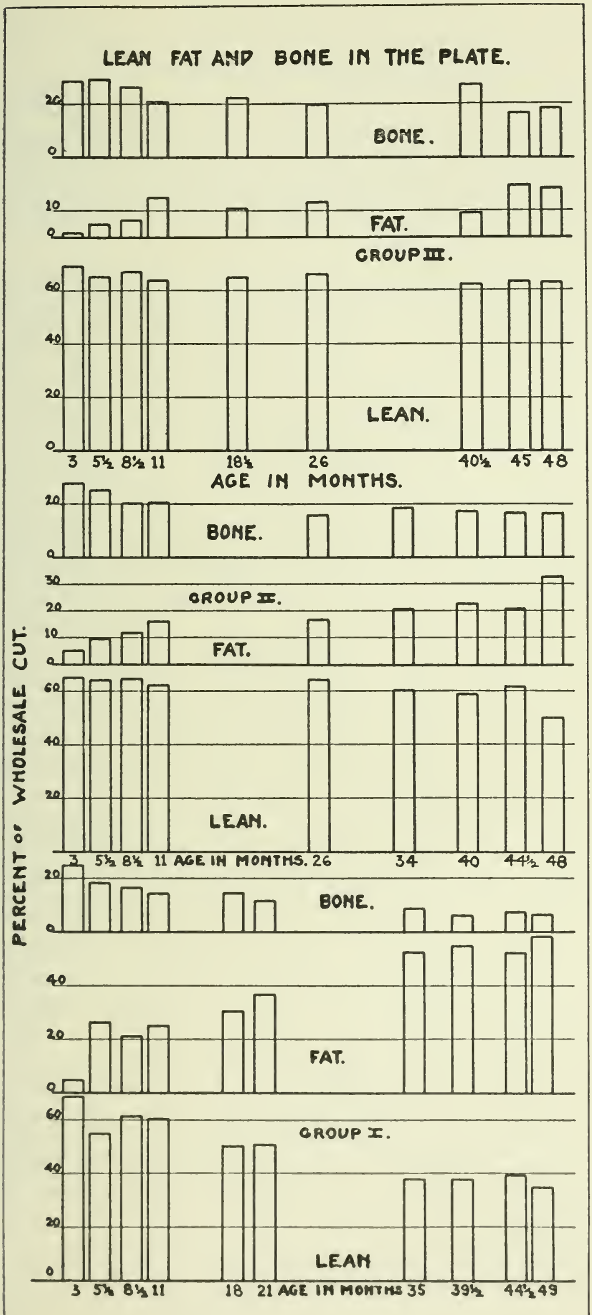

Fig. 22.—Distribution of lean, fat and bone in the plate.

with the Group I animals. The lean is 6.9 to 35 percent of the cut, the fat 5 to 58 percent, and the bone 25 to 7 percent.

The Group II animals show less extensive changes. The lean runs 65 to 60 percent except in the case of the oldest animal where, on account of a large increase in fat, it drops to 50 percent. The fat runs from about 6 to 35 percent and the bone 28 to 17 percent. The lean decreases slightly with age. The bone decreases with age while the fat increases.

With the Group III steers the lean runs 69 to 63 percent, the fat 2 to 19 percent, and the bone 29 to 17 percent. There is a very slight decrease in percent lean with increasing age. The fat increases while the bone decreases with increasing age.

The Rib.—Figure 23 shows the composition of the rib. With the Group I steers the lean runs from 66 to 37 percent, the fat from 2 to 51 percent, and the bone from 33 to 11 percent. The lean and bone decrease while the fat greatly increases with increasing age.

With the Group II animals the changes are less extreme. The lean runs from 68 to 58 percent, the fat from nothing to 19 percent, and the bone from about 32 to 22 percent. The lean and bone decrease with increasing age while the fat increases.

The Group III animals show a fairly constant percent of lean, 65 to 70 percent. The fat runs from nothing to 9 percent and the bone from 33 to 21 and 25 percent. The fat increases slightly with age while the bone decreases.

The Loin.—The loin is another cut that becomes very fat with increasing age. The Group I steers (Figure 24) have from 69 to 37 percent lean, 8 to 57 percent fat and 23 to 7 percent bone. The lean and bone decrease while the fat increases with age.

With the Group II animals the lean decreases from 70 percent to 57 and the bone from 23 to about 14 percent. The fat on the other hand increases from 5 to 25 percent.

The Group III steers show similar changes. The lean decreases from 74 to 67 percent and the fat increases from 4 to 18 percent. The bone increases from 20 to 25 percent and then drops to 15 to 17 percent. The steer 40½ months old seems to be abnormal in composition.

The Flank.—The flank becomes the fattest cut of them all (Figure 25). The Group I animals have in this cut from 69 to 24 percent lean and from 27 to 75 percent fat. The amount of bone is insignificant being generally below one percent. With the Group

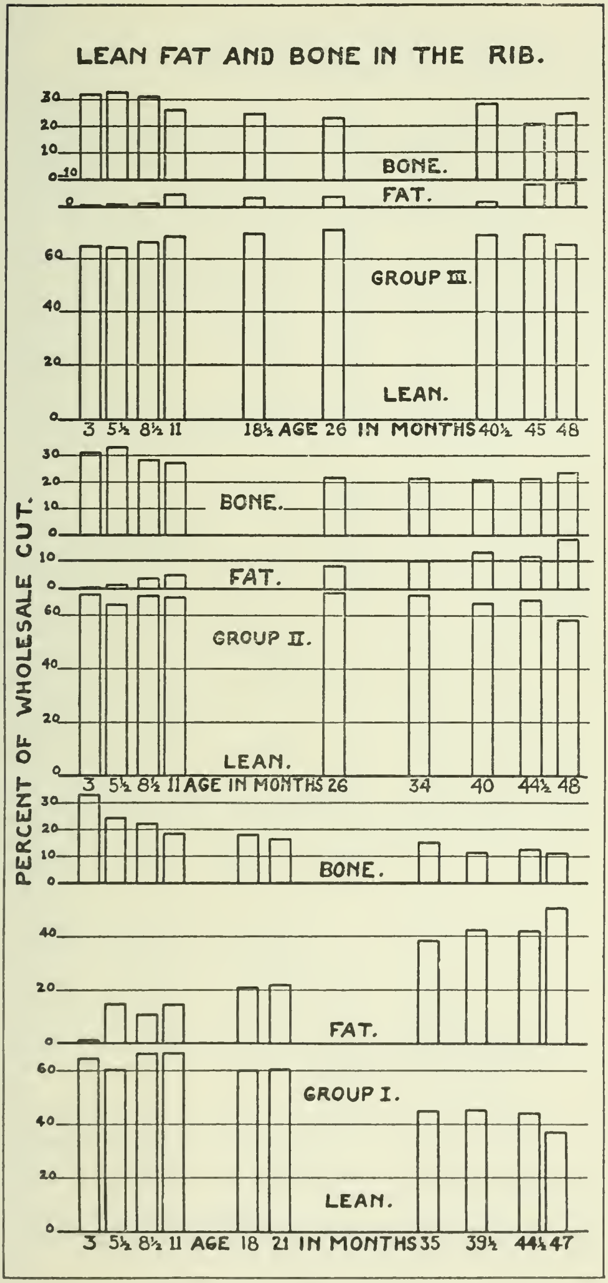

Fig. 23.—Distribution of lean, fat and bone in the rib.

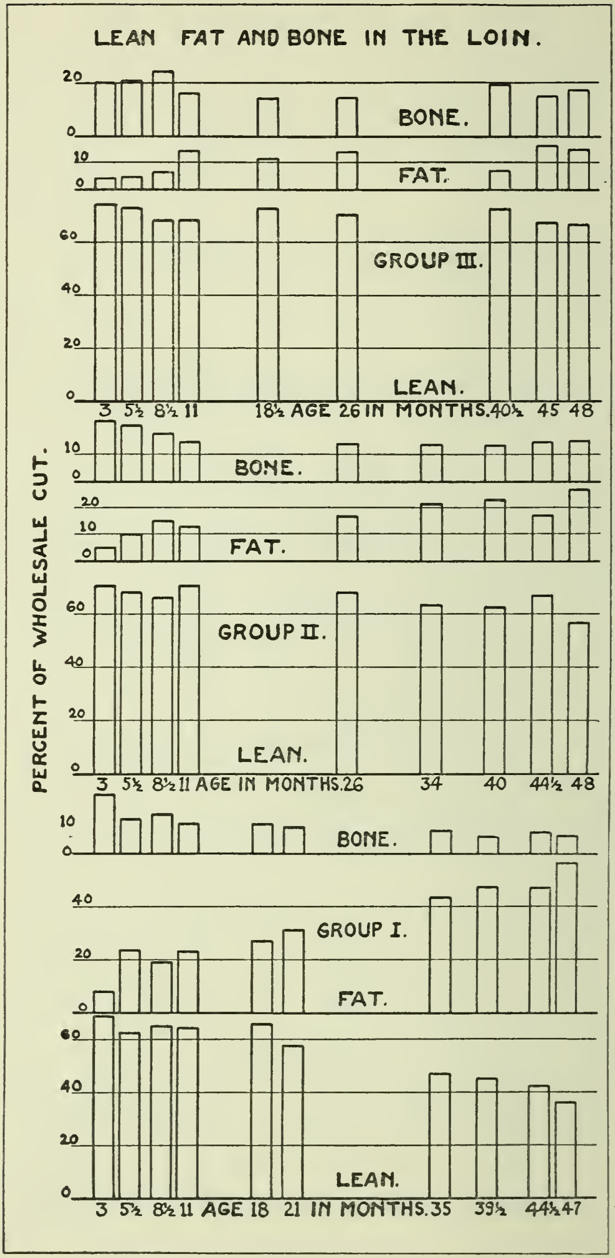

Fig. 24.—Distribution of lean, fat and bone in the loin.

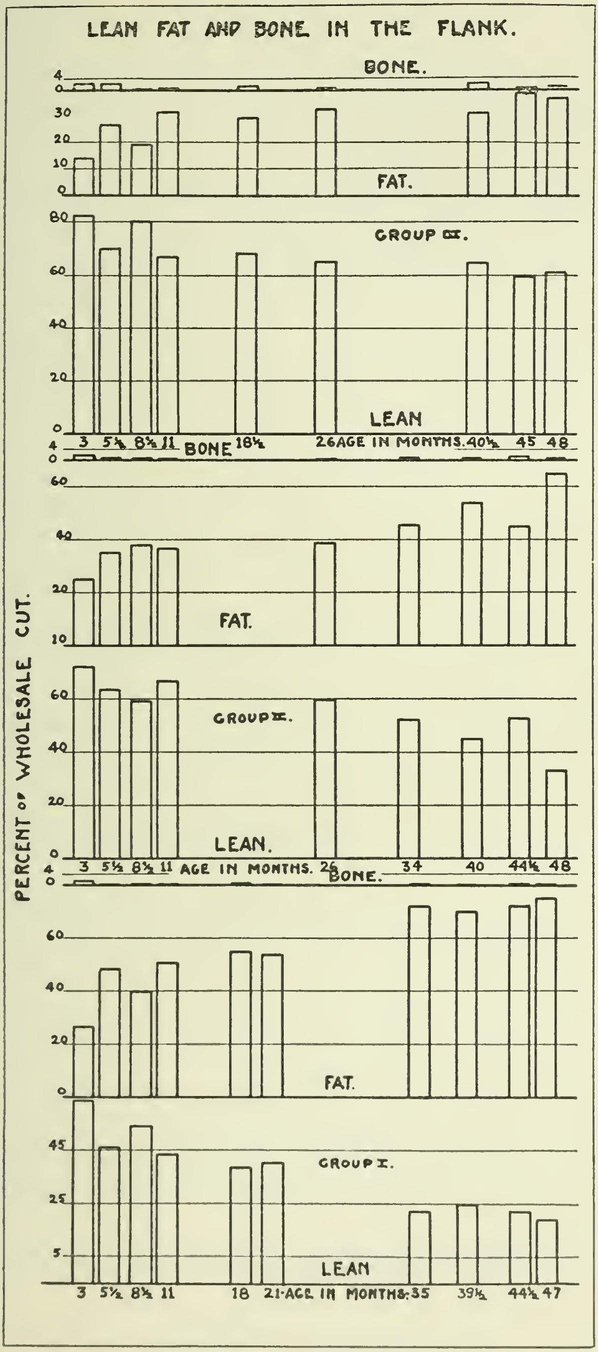

Fig. 25.—Distribution of lean, fat and bone in the flank.

II steers the lean decreases from 72 percent to 33 percent while the fat increases from 25 to 65 percent. With the Group III steers the lean decreases from about 83 to 60 percent, while the fat increases from 14 to 38 percent. In all groups then the fat increases with age while the lean decreases.

The Rump.—The changes in the composition of the rump are shown in Figure 26. With the Group I animals the lean decreases from 59 to about 30 percent while the fat increases from 8 to 56 percent. The bone decreases from 33 to 14 percent.

With the Group II animals with one striking exception the lean decreases with age running from 50 to 56 percent down to 44 percent. The fat increases from 8 to 32 percent, while the bone decreases from 41 to 23 percent.

In the case of the Group III steers the lean decreases from about 58 percent to 49 percent, and the fat increases from 5 to 21 percent. The bone increases at first from 36 to 39 percent and then decreases to 28 percent.

The Round.—The round shows rather small relative changes (Figure 27). The Group I steers have from 78 to 63 percent lean, from 5 to 28 percent fat, and from 16 to 9 percent bone. The Group II animals have about 80 percent lean in all cases but the oldest. The fat runs from 5 to 16 percent and the bone from 17 to about 12 percent. In Group III the lean runs between 77 and 81 percent, the fat increases from 4 to 9 percent and the bone decreases from 18 to about 12 percent.

The Shank.—The shank also shows small relative changes in make up. Figure 28 gives the distribution. The Group I steers have about 30 percent lean with a few animals running higher. The fat increases from 2 to 16 percent, but the next to the oldest shows 22.5 percent. The bone decreases from 66 to about 50 percent.

With the Group II steers the lean is fairly constant after 11 months at about 36 percent. At 3 months it is 29 percent. The fat is small and increases irregularly with age. The bone decreases from 69 percent to a value running around 60 percent from 11 months on.

The Group III animals show much the same thing as the Group II steers.

This is a very bony cut and after 8½ months it is not much affected by age.

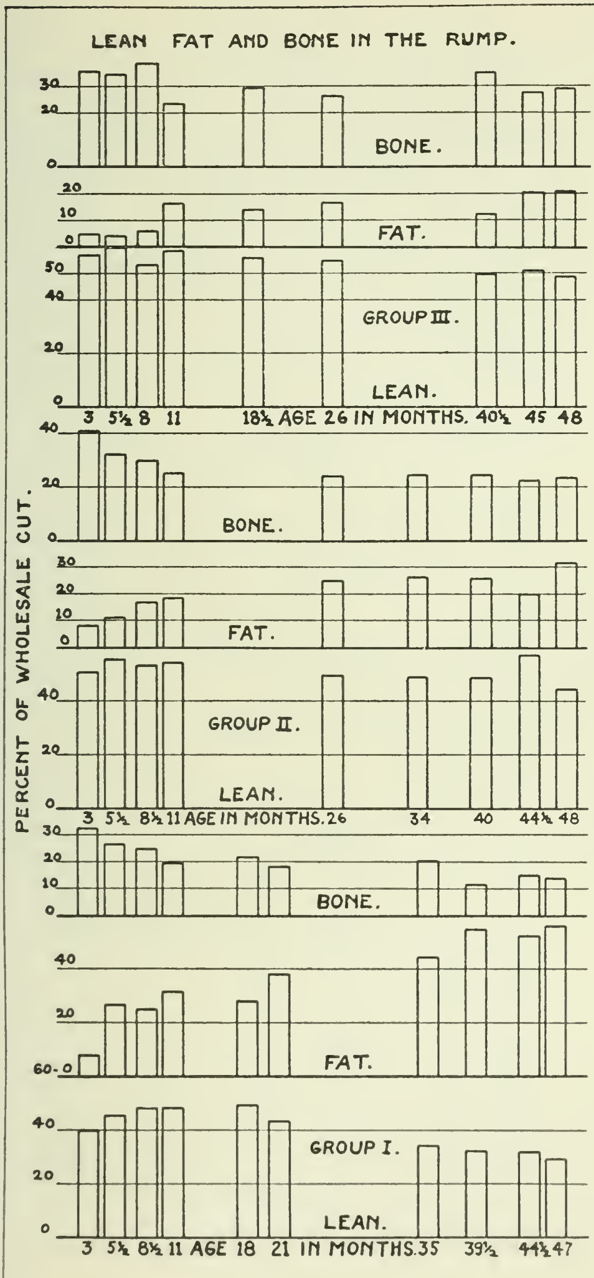

Fig. 26.—Distribution of lean, fat and bone in the rump.

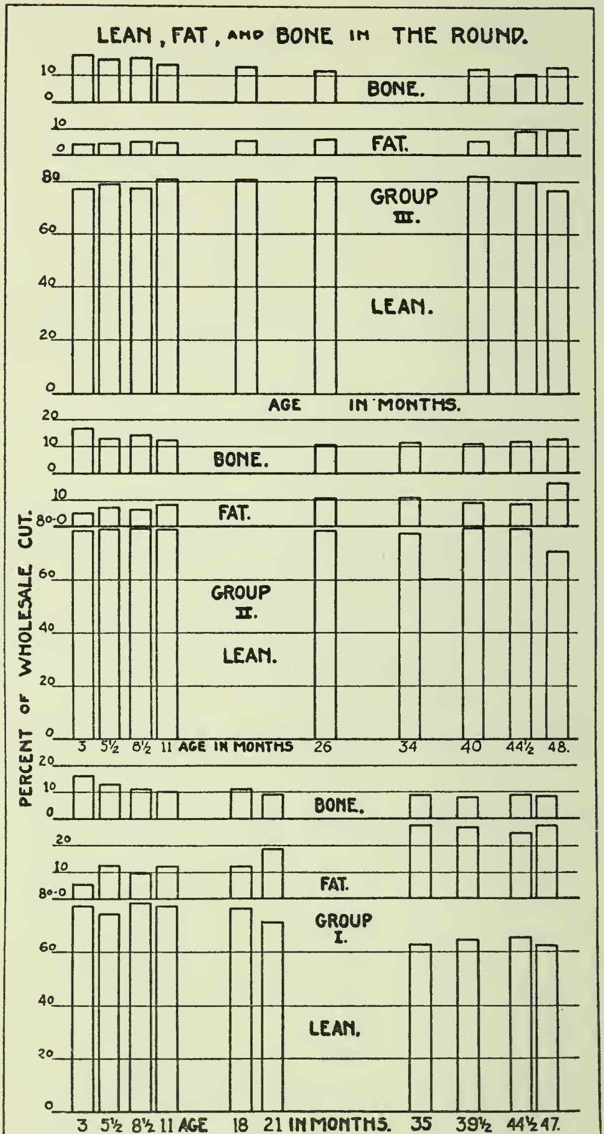

Fig. 27.—Distribution of lean, fat and bone in the round.

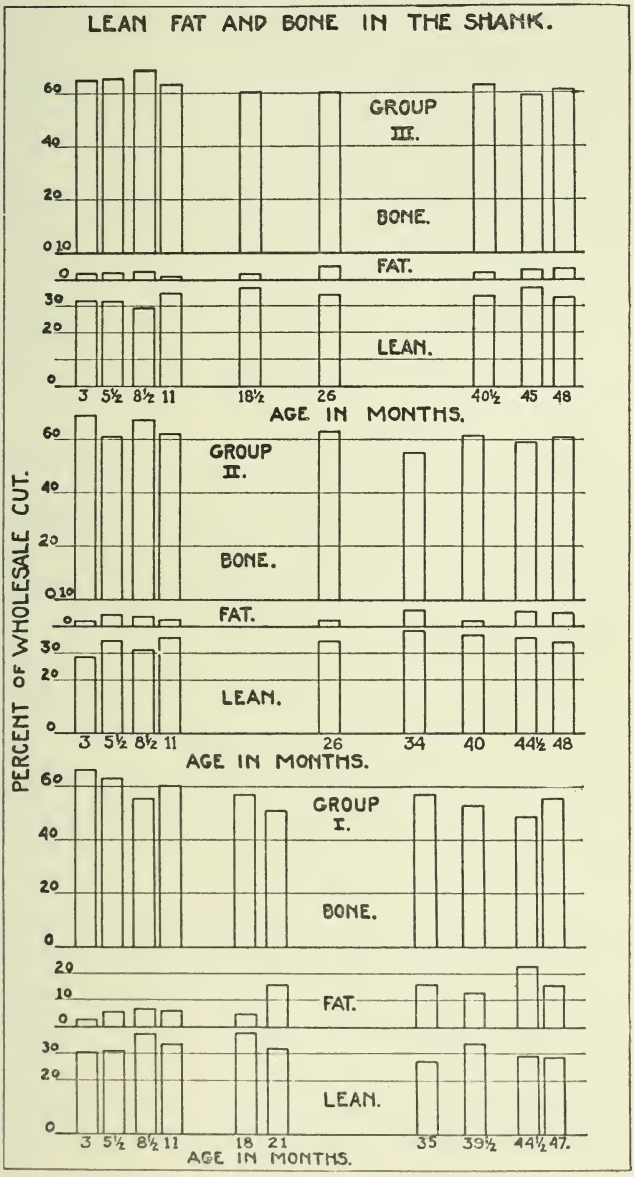

Fig. 28.—Distribution of lean, fat and bone in the shank.

SUMMARY

Hereford-Shorthorn beef steers were fed on three planes of nutrition: Group I, full fed from birth; Group II, fed for maximum growth without fattening giving gains of one pound per day for the first two years; Group III, fed for scanty or retarded growth gaining about .69 pounds per day for the first two years. The slaughter house data for 31 animals are presented.

With these animals the ratio of empty weight to live weight is greatest at birth, least at 8½ months, and intermediate at 4 years. A lower plane of nutrition gives a lower ratio.

The ratio of carcass to live weight decreases to 8½ months then increases to a maximum at 3 to 4 years. The better fed animals have the greater percent. On the empty weight basis the carcass continuously increases to 3 to 4 years.

The proportions of hide and hair, heart, brain and spinal cord, and intestinal length to empty weight decrease with increasing age and fatness. The blood, lungs, stomachs, intestines (weight), liver, kidneys, spleen, and pancreas increase relatively during the early months and then decrease. The maxima occur generally at 8½ months. The stomachs and liver show marked retardation on the low planes of nutrition.

The proportions of skeleton and of total organs are greatest at birth and the total fleshy parts at 4 years.

In the carcass the proportions of loin, rump, flank, and plate increase with increasing age and fatness of the steers. The rib changes but little while the round, chuck and neck, and shin and shank decrease.

The distribution of the total lean flesh is but little affected by age and fatness excepting that there is a slight reduction in the proportion found in the shin, shank, head and tail and in some cases in the round. The plate shows a larger part of the total as the animal grows and fattens.

The proportion of the total fat flesh found in the plate, rib, loin, and in some cases in the rump increases with increasing fatness.

Age and fatness influence the distribution of the total skeleton but slightly. The feet bones tend to increase relatively up to 8½ months (Group I) and then decrease. The chuck and neck

bones show a similar phenomenon with the maximum at 18 months. The rump shows a slight increase.

The composition of the wholesale cuts of meat is affected by increasing age and fatness. In general the percent of fatty tissue increases and the percent of bone decreases. The percent of lean flesh may increase, remain constant, or decrease, but on the average it decreases. The increases in percent of fat are greatest in the plate, loin, and flank. The rib and rump show rather large increases.

APPENDIX

TABLE 1.—SLAUGHTER HOUSE WEIGHTS OF OFFAL PARTS (IN GRAMS).

Steer	556	554	555	557	552	548
Age	3 Months	3 Months	3 Months	5 Months 17 Days	5 Months 7 Days	5 Months 9 Days
Group	1	2	3	1	2	3
Live weight	111,489	87,456	84,725	204,934	116,491	99,255
Blood	6,124	4,197	4,529	8,952	5,219	4,603
Heart, pericardium, arteries	993	591	554	2,342	1,056	753
Heart, marketable	521	335	315	928	561	427
Heart, lean	432	319	295	760	561	385
Lungs and trachea	1,272	907	937	1,972	1,096	1,084
Brain	275	273	252	351	332	374
Spinal cord	123	122	101	200	134	152
Tongue, including bones and larynx	884	660	432	908	673	571
Tongue, marketable	466	358	247	650	464	428
Tongue bones, including larynx	106	142	53	131	96	88
Gullet	209	146	193	189	355	204
Stomachs	1,975	1,208	1,338	4,341	1,938	1,885
Rumen	999	616	745	2,614	1,100	975
Reticulum	260	147	147	358	188	203
Omasum	391	161	176	724	374	363
Abomasum	325	284	270	645	276	344
Intestines, small	1,944	1,474	1,651	2,863	1,781	1,660
Intestines, large	750	603	792	1,233	1,003	861
Intestines, small; length, cm	2,878	2,452	2,080	3,139	2,630	2,806
Intestines, large; length, cm	540	450	380	667	491	550
Neck sweetbread	173	193	129	359	143	109
Heart sweetbread	155	143	30	264	122	59
Spleen	300	202	167	485	284	215
Pancreas	96	76	106	225	101	85
Liver	1,760	1,166	1,240	3,003	1,181	1,104
Gall bladder and gall	25	23	8	148	55	34
Gall	....	....	....	87	40	....
Kidneys	338	530	439	649	316	353
Urinary bladder	46	58	63	76	41	53
Penis	110	116	59	155	94	79
Diaphragm	166	70	51	199	92	98
Caul fat	417	170	107	1,981	363	....
Stomach fat	146	73	20	1,486	469	275
Intestinal fat	839	401	335	3,290	952	570
Hide and hair	10,314	7,400	6,580	14,100	10,532	8,328
Dewclaws	32	28	24	64	66	36
Teeth	218	225	190	261	278	264
Horns	....	9	....	46	36	40
Hoofs	358	301	274	585	448	359
Right fore foot and hoof	761	666	610	1,035	828	728
Left fore foot and hoof	760	653	630	1,007	807	728
Right hind foot and hoof	719	651	596	1,005	882	740
Left hind foot and hoof	707	734	595	1,096	792	659
Fore quarter, right	15,436	13,096	12,075	28,483	16,023	13,944
Hind quarter, right	14,849	12,358	10,596	27,438	15,135	12,764
Left half	30,129	24,675	22,764	54,150	30,580	27,275

TABLE 2.—SLAUGHTER HOUSE WEIGHTS OF OFFAL PARTS (IN GRAMS).

Steer	547	550	558	541	538	540
Age	8 Months 5 Days	8 Months 14 Days	8 Months 12 Days	10 Months 22 Days	10 Months 26 Days	11 Months 2 Days
Group	1	2	3	1	2	3
Live weight	206,175	147,202	108,191	323,836	180,930	158,131
Blood	8,711	7,080	4,666	12,470	7,219	6,967
Heart, pericardium, arteries	1,624	1,163	971	2,646	1,670	1,436
Heart, marketable	771	556	506	1,087	873	673
Heart, lean	666	481	425	940	698	572
Lungs and trachea	1,868	1,460	1,111	2,387	1,825	1,501
Brain	346	319	373	383	343	361
Spinal cord	113	124	147	185	144	151
Tongue, including bones and larynx	800	834	650	2,336	1,513	1,547
Tongue, marketable	586	523	464	1,209	779	811
Tongue bones, including larynx	161	139	111	309	221	170
Gullet	384	209	331	538	400	324
Stomachs	5,190	3,833	2,550	7,876	4,521	3.894
Rumen	3,127	1,914	1,329	4,050	2,209	1,966
Reticulum	373	366	253	866	751	470
Omasum	1,072	1,015	579	1,885	1,013	878
Abomasum	618	538	389	1,075	548	480
Intestines, small	2,649	2.303	1,599	3,922	2,327	1,954
Intestines, large	1.826	1,321	1,018	1,322	1.319	1,305
Intestines, small; length, cm	2.900	2,755	2,568	3,343	3,393	2,510
Intestines, large; length, cm	663	620	531	716	610	772
Neck sweetbread	372	189	73	396	252	194
Heart sweetbread	319	147	59	344	229	214
Spleen	391	291	193	596	331	331
Pancreas	200	200	153	390	208	180
Liver	2,851	1,992	1,352	3,832	1,978	1,593
Gall bladder and gall	138	117	28	275	153	83
Gall	103	86	7	202	122	58
Kidneys	450	379	318	645	487	363
Urinary bladder	83	60	48	153	123	134
Penis	181	112	149	226	146	131
Diaphragm	198	170	116	176	131	136
Caul fat	1,118	532	150	4,212	939	578
Stomach fat	851	781	248	1,803	799	469
Intestinal fat	1,910	1,297	431	4,322	1,714	1,260
Hide and hair	14,618	10,440	8,138	26,576	15,342	12,994
Dewclaws	86	53	38	99	65	49
Teeth	310	228	274	304	240	278
Horns	77	112	31	468	250	304
Hoofs	574	384	374	770	570	432
Right fore foot and hoof	1,177	820	764	1,270	931	803
Left fore foot and hoof	999	780	719	1,303	935	813
Right hind foot and hoof	1,185	778	771	1,368	937	805
Left hind foot and hoof	1,054	765	719	1,340	935	819
Fore quarter, right	27,711	19,194	14,089	46,507	25,401	21,605
Hind quarter, right	28,561	18,582	13,921	47,873	24,824	20,820
Left half	55,406	36,500	27,259	95,368	46,859	44,904

TABLE 3.—SLAUGHTER HOUSE WEIGHTS OF OFFAL PARTS (IN GRAMS).

Steer	505	503	532	531	504	523	525
Age	10 mo. 18 da.	11 mo. 11 da.	1 yr. 5 mo. 20 da.	1 yr. 6 mo. 12 da.	1 yr. 8 mo. 26 da.	2 yr. 2 mo. 6 da.	2 yr. 2 mo. 8 da.
Group	1	2	1	3	1	2	3
Live weight	313,317	270,566	517,093	212,466	526,164	380,880	305,112
Blood	13,810	13,058	18,752	9,457	21,005	15,287	13,614
Heart, pericardium, arteries	2,106	2,845	4,843	1,971	3,065	3,004	1,320
Heart, marketable	1,056	1,251	2,058	1,011	1,632	1,477	1,169
Heart, lean	938	1,063	1,685	791	1,428	1,188	1,005
Lungs and trachea	2,498	2,549	3,870	1,915	3,628	3,371	1,658
Brain	376	442	406	373	423	475	467
Spinal cord	161	224	237	200	301	322	244
Tongue, including bones and larynx	1,989	1,365	3,195	1,728	3,904	3,702	2,554
Tongue, marketable	1,115	789	1,543	894	1,587	1,678	1,276
Tongue bones, including larynx	190	204	340	207	367	404	252
Gullet	311	442	744	494	455	803	525
Stomachs	8,818	5,765	10,893	5,343	12,820	9,342	8,849
Rumen	....	....	5,943	2,740	....	....	....
Reticulum	....	....	1,272	593	....	....	....
Omasum	....	....	2,208	1,117	....	....	....
Abomasum	....	....	1,470	893	....	....	....
Intestines, small	4,852	4,736	3,792	2,346	9,526	5,226	5,960
Intestines, large			2,132	1,342			
Intestines, small; length, cm	4,460	4,039	4,389	2,926	4,125	3,797	....
Intestines, large; length, cm	....	909	975	762	1,054	866	....
Neck sweetbread	425	348	321	236	396	272	150
Heart sweetbread	337	399	120	236	532	341	145
Spleen	599	661	884	481	1,317	847	556
Pancreas	300	289	630	297	295	300	151
Liver	3,983	3,646	5,694	2,205	4,754	3,268	2,876
Gall bladder and gall	215	201	284	114	697	146	126
Gall	....	....	185	86	....	....	....
Kidneys	718	655	868	506	877	703	664
Urinary bladder	80	108	308	223	254	254	193
Penis	251	288	302	240	310	196	157
Diaphragm	204	917	626	270	1,819	362	343
Caul fat	....	....	8,735	686	....	2,156	1,132
Stomach fat	6,344	3,771	4,940	586	12,272	2,156	1,180
Intestinal fat	6,437	3,614	10,022	1,627	12,833	3,603	2,649
Hide and hair	23,026	23,120	33,988	16,693	41,144	33,097	27,813
Dewclaws	142	112	158	90	198	115	88
Teeth	268	253	494	426	338	766	690
Horns	342	285	228	....	1,272	1,167	1,298
Hoofs	722	661	1,248	700	1,062	948	852
Right fore foot and hoof	1,218	1,456	1,937	1,095	1,767	1,609	1,380
Left fore foot and hoof	1,218	1,469	1,968	1,096	1,815	1,664	1,380
Right hind foot and hoof	1,251	1,350	1,932	1,136	1,736	1,649	1,320
Left hind foot and hoof	1,251	1,383	1,878	1,137	1,805	1,608	1,289
Fore quarter, right	45,336	37,450	79,605	29,683	76,580	56,114	43,204
Hind quarter, right	43,630	36,954	76,799	29,429	81,101	53,785	39,581
Left half	87,885	71,832	156,225	59,900	148,728	....	....

TABLE 4.—SLAUGHTER HOUSE WEIGHTS OF OFFAL PARTS (IN GRAMS).

Steer	515	507	529	527	526	524
Age	2 yr. 9 mo. 19 days	2 yr. 9 mo. 16 days	3 yr. 2 mo. 21 days	3 yr. 3 mo. 15 days	3 yr. 4 mo.	3 yr. 4 mo. 13 days
Group	1	2	1	1	2	3
Live weight	743,361	457,155	690,704	842,841	479,846	362,260
Blood	27,856	20,316	23,028	27,382	18,957	17,019
Heart, pericardium, arteries	5,787	4,278	5,713	8,891	3,998	2,953
Heart, marketable	2,664	2,061	2,045	3,246	1,673	1,585
Heart, lean	1,890	1,556	1,419	2,370	1,246	1,369
Lungs and trachea	3,653	3,768	4,272	4,326	3,797	3,455
Brain	483	482	443	407	469	508
Spinal cord	245	262	261	294	191	250
Tongue, including bones and larynx	4,229	3,697	4,021	5,734	3,626	3,602
Tongue, marketable	2,309	1,791	1,603	1,904	1,769	1,666
Tongue bones, including larynx	484	467	441	420	438	435
Gullet	627	709	829	1,090	777	1,340
Stomachs	13,171	9,620	12,101	10,347	10,985	8,096
Rumen	....	....	6,007	5,790	6,091	4,602
Reticulum	....	....	1,069	889	896	775
Omasum	....	....	3,179	2,361	2,460	1,457
Abomasum	....	....	1,846	1,307	1,538	1,262
Intestines, small	6,823	5,625	2,985	2,539	2,257	1,964
Intestines, large			2,304	2,508	1,877	2,032
Intestines, small; length, cm	4,694	3,962	3,818	3,861	3,515	2,911
Intestines, large; length, cm			1,036	1,072	925	747
Neck sweetbread	484	325	514	464	269	267
Heart sweetbread	447	318	552	573	170	274
Spleen	1,482	1,132	1,049	1,226	831	757
Pancreas	424	231	824	849	498	435
Liver	5,982	3,788	5,374	5,720	3,531	3,019
Gall bladder and gall	382	130	280	149	231	296
Gall	....	....	190	10	143	229
Kidneys	1,065	752	1,006	1,244	922	766
Urinary bladder	347	282	257	295	312	361
Penis	225	239	436	300	250	365
Diaphragm	1,107	1,036	645	1,276	807	532
Caul fat	9,263	3,859	13,993	14,263	2,763	1,068
Stomach fat	6,965	3,097	10,951	9,669	2,815	1,244
Intestinal fat	13,649	4,351	14,112	24,585	5,973	2,695
Hide and hair	49,943	34,473	45,567	46,240	35,732	30,092
Dewclaws	201	152	241	240	227	194
Teeth	786	712	....	872	782	806
Horns	1,804	1,600	2,200	1,266	1,427	1,227
Hoofs	1,692	1,338	....	1,934	1,648	1,300
Hight fore foot and hoof	2,346	1,936	2,213	2,293	2,031	1,864
Left fore foot and hoof	2,312	1,938	2,230	2,321	1,984	1,867
Right hind foot and hoof	2,473	1,884	2,331	2,265	1,862	1,791
Left hind foot and hoof	2,607	1,900	2,362	2,306	1,863	1,815
Fore quarter, right	115,806	72,574	111,434	147,674	75,917	54,798
Hind quarter, right	112,738	65,693	112,704	141,372	70,858	50,394
Left half	....	....	229,567	304,508	....	....

TABLE 5.—SLAUGHTER HOUSE WEIGHTS OF OFFAL PARTS (IN GRAMS).

Steer	513	502	509	501	512	500
Age	3 yr. 8 mo. 15 days	3 yr. 8 mo. 19 days	3 yr. 8 mo. 22 days	3 yr. 11 mo.	3 yr. 11 mo. 21 days	3 yr. 11 mo. 26 days
Group	1	2	3	1	2	3
Live weight	854,650	506,878	439,814	883,480	548,050	457,786
Blood	25,680	19,728	18,291	28,710	24,176	21,269
Heart, per cardium, arteries	7,427	4,451	3,645	6,177	5,158	3,414
Heart, marketable	2,311	1,946	1,660	2,214	1,955	1,467
Heart, lean	2,003	1,680	1,444	1,882	1,555	1,284
Lungs and trachea	4,858	3,696	3,283	3,838	3,881	3,747
Brain	413	465	389	459	466	422
Spinal cord	335	335	350	298	200	410
Tongue, including bones and larynx	4,171	4,107	3,317	5,294	4,215	3,541
Tongue, marketable	1,942	2,198	1,555	2,153	1,766	1,619
Tongue bones, including larynx	455	499	425	500	526	439
Gullet	1,152	1,098	1,081	1,051	973	909
Stomachs	13,446	10,832	9,851	14,185	11,089	10,995
Rumen	7,704	7,216	5,274	8,769	5,867	6,446
Reticulum	1,431	....	1,064	933	1,068	1,045
Omasum	2,951	2,218	2,337	2,976	2,643	2,419
Abomasum	1,360	1,398	1,176	1,507	1,511	1.085
Intestines, small	3,543	2.324	2,186	2,796	3,067	2,645
Intestines, large	2,327	1,829	1,703	2,079	2,255	1,890
Intestines, small; length, cm	4,480	3,545	3,255	3,848	4,481	3,388
Intestines, large; length, cm	1,054	970	901	1,001	1,067	945
Neck sweetbread	581	338	267	335	235	250
Heart sweetbread	753	164	363	449	276	288
Spleen	1,114	921	1,304	1,178	1,255	1,054
Pancreas	873	581	562	836	736	625
Liver	5,920	3,716	3,875	6,161	4,416	4,634
Gall bladder and gall	127	334	225	266	300	300
Gall	37	241	110	176	212	241
Kidneys	1,015	838	774	1,037	1,074	1,019
Urinary bladder	227	283	253	275	366	331
Penis	330	305	274	339	302	271
Diaphragm	811	561	661	779	672	692
Caul fat	24.621	2,738	2,937	14,688	5,545	3,930
Stomach fat	7,860	3,256	2,240	7,432	3,658	2,968
Intestinal fat	21,290	5,383	4,745	16,503	8,251	6.042
Hide and hair	45,286	39,556	37,614	50,090	41,268	35,938
Dewclaws	308	218	196	331	234	247
Teeth	874	1,038	838	778	710	852
Horns	2,144	1,949	....	3,354	1,810	....
Hoofs	1,872	1,792	1,394	2,192	1,490	1,848
Right fore foot and hoof	2,452	2,272	1,941	2,466	2,210	2,226
Left fore foot and hoof	2,426	2,277	1,904	2,467	2,184	2,141
Right hind foot and hoof	2.283	2,115	1,828	2,502	2,043	2,117
Left hind foot and hoof	2,432	2,115	1,875	2,569	2,008	2,126
Fore quarter, right	146,424	80,313	70,406	152.353	90,208	71,295
Hind quarter, right	132,093	73,106	63,182	151,476	79,228	64,330
Left half	278,645	152,147	131,803	305,356	169,239	136,107

TABLE 6.—SLAUGHTER HOUSE WEIGHTS OF CARCASS PARTS (IN GRAMS).

Steer	556	554	555	557	552	548
Age	3 months	3 months	3 months	5 mo. 17 da.	5 mo. 7 da.	5 mo. 9 da
Group	1	2	3	1	2	3
Head, total	3,338	2,895	2,833	5,614	4,059	4,033
Lean, total	702	667	765	1,048	795	996
Fat, total	132	141	143	728	308	118
Bone, total	2,504	2,087	1,925	3,838	2,956	2,901
Shin, right	1,765	1,468	1,637	2,465	1,700	1,592
Lean, right	840	645	829	1,159	864	735
Fat, right	81	81	71	194	70	51
Bone, right	851	732	727	1,123	775	792
Neck, right	517	414	502	769	428	527
Lean, right	344	231	287	423	266	287
Fat, right	71	51	....	149	54	55
Bone, right	100	133	215	206	114	191
Chuck, right	7,600	6,744	5,863	13,088	7,851	6,866
Lean, right	5,465	4,795	4,298	8,783	5,613	5,033
Fat, right	323	188	116	1,718	409	193
Bone, right	1,767	1,733	1,448	2,613	1,840	1,624
Plate, right	3,048	2,245	2,107	6,739	2,940	2,525
Lean right	2,096	1,475	1,461	3,710	1,887	1,655
Fat, right	156	125	42	1,769	288	131
Bone, right	773	628	605	1,241	750	741
Rib right	2.485	2,144	1,915	5,276	3,120	2,412
Lean, right	1,611	1,457	1.256	3,186	1,995	1,570
Fat, right	39	....	....	808	57	20
Bone, right	823	677	628	1,286	1,042	807
Loin, right	5,029	4,088	3,102	9,367	5,147	3,864
Lean, right	3,469	2,906	2,309	5,857	3,517	2,834
Fat, right	410	214	137	2,236	521	192
Bone, right	1,134	934	632	1,239	1,096	826
Kidney, Fat, right	210	120	65	1,614	250	142
Flank, right	868	533	549	2,169	935	630
Lean, right	599	384	453	1,117	597	445
Fat, right	236	134	78	1,051	330	170
Bone, right	16	11	13	8	8	16
Rump, right	926	891	703	1,779	987	811
Lean, right	548	453	401	814	551	485
Fat, right	74	73	37	477	112	36
Bone, right	304	366	253	480	320	285
Round, right	6,106	5,064	4,600	10,090	6,230	5,811
Lean, right	4,736	3,959	3,563	7,480	4,915	4,604
Fat, right	343	260	188	1.266	454	260
Bone, right	987	851	826	1,343	813	949
Shank, right	1,478	1,395	1,309	2,064	1,429	1,305
Lean, right	447	400	417	628	495	415
Fat, right	36	26	27	117	59	30
Bone, right	976	959	852	1,305	871	856
Tail, total	172	200	122	332	237	147
Lean, total	80	75	48	106	106	53
Fat, total	....	....	....	33	....	....
Bone, total	92	125	74	193	131	94

TABLE 7.—SLAUGHTER HOUSE WEIGHTS OF CARCASS PARTS (IN GRAMS).

Steer	547	550	558	541	538	540
Age	8 mo. 5 da.	8 mo. 14 da.	8 mo. 12 da.	10mo.22da.	10mo.26da.	11 mo. 2 da.
Group	1	2	3	1	2	3
Head, total	6,461	5,108	4,764	6,939	5,178	4,747
Lean, total	2,532	1,704	1,388	1,388	1,118	890
Fat, total	808	384	312	460	280	344
Bone, total	3,121	3,020	3,064	5,091	3,780	3,513
Shin, right	2,487	1,951	1,705	3,712	2,400	2,228
Lean, right	1,378	991	778	1,927	1,197	1,167
Fat, right	169	65	51	318	96	69
Bone, right	928	876	864	1,473	1,104	976
Neck, right	525	451	343	1,500	856	689
Lean right	303	259	209	976	503	452
Fat, right	115	40	20	183	164	20
Bone, right	109	147	103	338	200	213
Chuck, right	13,902	9,962	7,557	22,782	13,036	10,763
Lean, right	10,100	6,880	5,343	16,871	9,442	7,771
Fat, right	1,300	728	269	2,210	1,033	746
Bone, right	2,451	2,331	1,925	3,310	2,506	2,235
Plate, right	5,804	3,745	2,055	10,165	5,120	4,374
Lean right	3,574	2,424	1,386	6,285	3,197	2,798
Fat, right	1,240	448	136	2,463	829	646
Bone, right	969	762	542	1,415	1,062	923
Rib, right	4,932	3,085	2,380	8,630	3,886	3,418
Lean, right	3,280	2,084	1,593	5,794	2,598	2,361
Fat, right	551	120	28	1,217	213	162
Bone, right	1,086	870	758	1,581	1,077	912
Loin, right	10,373	6,840	4,359	17,833	8,957	7,803
Lean, right	6,788	4,536	2,981	11,708	6,366	5,350
Fat, right	1,986	1,067	300	4,044	1,180	1,154
Bone, right	1,566	1,232	1,069	1,958	1,348	1,275
Kidney, Fat, right	815	378	113	3,028	311	341
Flank, right	2,317	1,101	575	3,725	1,434	973
Lean, right	1,372	656	462	1,670	961	657
Fat, right	927	420	112	2,037	531	311
Bone, right	10	8	4	17	10	8
Rump, right	1,531	1,180	866	2,765	1,436	1,300
Lean, right	740	631	463	1,378	780	764
Fat, right	388	200	52	849	268	218
Bone, right	380	350	339	528	366	311
Round, right	10,871	7,391	6,223	17,065	10,294	8,305
Lean, right	8,546	5,860	4,382	13,500	8,162	6,728
Fat, right	1,075	472	322	1,927	851	405
Bone' right	1,244	1,050	1,047	1,625	1,278	1,175
Shank, right	2,285	1,502	1,537	3,042	2,106	1,810
Lean, right	856	435	432	981	754	629
Fat, right	148	56	42	189	48	16
Bone, right	1,267	1,011	1,053	1,872	1,304	1,152
Tail, total	292	186	98	381	229	217
Lean, total	138	88	18	160	82	36
Fat, total	9	4	....	54	16	4
Bone, total	144	94	80	206	135	138

TABLE 8.—SLAUGHTER HOUSE WEIGHTS OF CARCASS PARTS (IN GRAMS).

Steer	505	503	532	531	504	523	525
Age	10 mo. 18 da.	11 mo. 11 da.	1 yr. 5 mo. 20 da.	1 yr. 6 mo. 12 da.	1yr.8 mo. 26 da.	2yr.2 mo. 6 da.	2yr.2 mo 8 da.
Group	1	2	1	3	1	2	3
Head, total	6.977	8,321	10,510	6,251	11,035	9,848	8,536
Lean, total	1,494	1,728	2,486	1,310	2,656	2,500	2,078
Fat, total	814	886	1,406	280	648	306	508
Bone, total	4,669	5,707	6,514	4,487	7,675	6,832	5,758
Shin, right	3,703	3,330	6,742	3,107	6,123	4,941	4,328
Lean, right	2,017	1,604	3,544	1,602	3,176	2,671	2,421
Fat, right	205	147	468	112	751	263	199
Bone, right	1,479	1,568	2,703	1,393	2,164	1,995	1,681
Neck, right	1,044	1,159	1,476	1,292	1,536	1,391	1,552
Lean, right	641	548	839	930	844	943	1,025
Fat, right	135	181	277	118	233	58	117
Bone, right	264	430	370	257	454	378	398
Chuck, right	21,957	18,821	38,288	15,303	34,645	28,898	20,626
Lean, right	15,877	14,040	27,000	11,524	23,092	21,723	15,605
Fat, right	2,519	1,198	4,986	879	5,735	2,436	1,165
Bone, right	3,497	3,384	6,137	2,792	5,134	4,515	3,827
Plate, right	9,943	7,580	18,479	5,483	18,905	11,995	8,556
Lean right	5,861	4,398	10,017	3,585	9,617	7,704	5,651
Fat, right	2,586	1,475	5,657	609	6,963	2,028	1,174
Bone, right	1,478	1,676	2,689	1,248	2,249	1,914	1,695
Rib, right	8,607	6,625	14,483	4,483	15,286	8,753	8,134
Lean, right	5,650	4,466	8,678	3,137	9,253	6,016	5,833
Fat, right	1,320	420	3,097	169	3,385	761	332
Bone, right	1,596	1,691	2,611	1,140	2,546	1,922	1.944
Loin, right	15,622	13,475	27,366	9,641	29,121	18,844	13,241
Lean, right	9,843	8,603	18,068	7,039	16,838	12,917	9,355
Fat, right	3.779	2,873	7,477	1,132	9,170	3,188	1.879
Bone, right	1,937	1,917	3,123	1,417	2,925	2,661	1,964
Kidney, Fat, right	2,877	1,063	5,867	363	5,700	1,555	629
Flank, right	3,665	2,330	6,692	1,253	8,280	3,795	2,598
Lean, right	1,912	1,480	2,934	861	3,778	2,279	1,704
Fat, right	1,738	792	3,710	372	4,467	1,481	852
Bone, right	20	42	50	25	37	27	32
Rump, right	2,786	2,146	5,190	1,783	6,631	3,627	2,876
Lean, right	1,300	1,012	2,570	1,001	2,884	1,799	1,589
Fat, right	914	591	1,459	252	2,539	910	488
Bone, right	553	525	1,141	530	1,214	885	771
Round, right	15,380	14,600	25,006	13,349	25,995	21,613	16,843
Lean, right	11,592	11,499	19,032	10,748	18,619	16,950	13.762
Fat, right	2,071	1,109	3,032	745	4,909	2,278	981
Bone, right	1,698	1,928	2,812	1,820	2,404	2,315	2,023
Shank, right	2,885	3,043	4,682	2,656	4,817	3,874	3,024
Lean, right	1,019	991	1,773	971	1,541	1,324	1,026
Fat, right	162	171	219	55	772	84	152
Bone, right	1,693	1,874	2,675	1,606	2,469	2,436	1,826
Tail, total	520	385	675	280	691	630	468
Lean, total	214	150	318	120	222	256	178
Fat, total	58	24	50	12	64	38	24
Bone, total	240	190	266	148	316	316	224

Table 9.—Slaughter House Weights of Carcass Parts (in Grams).

Steer	515	507	529	527	526	524
Age	2 yr. 9 mo. 19 da.	2 yr. 9 mo. 16 da.	3 yr. 2 mo. 21 da.	3 yr. 3 mo. 15 da.	3 yr. 4 mo.	3 yr. 4 mo. 13 da.
Group	1	2	1	1	2	3
Head, total	14,869	11,874	13,249	12,838	11,643	10,915
Lean, total	2,990	2,370	....	3,362	2,426	2,382
Fat, total	2,484	1,352	....	1,246	822	740
Bone, total	9,395	8,152	....	8,032	8,395	7,593
Shin, right	8,370	6,313	8,275	8,824	6,789	5,333
Lean, right	3,822	3,519	....	4,371	3,704	2,631
Fat, right	1,538	258	....	1,281	248	189
Bone, right	3,009	2,510	....	3,170	2,820	2,475
Neck, right	2,288	1,611	1,587	1,832	1,812	1,473
Lean, right	1,110	998	....	729	1,047	902
Fat, right	667	179	....	603	333	38
Bone, right	508	417	....	508	425	526
Chuck, right	49,301	36,460	47,355	62,001	35,906	28,236
Lean, right	31,074	27,311	....	36,160	25,478	21,342
Fat, right	11,216	2,777	....	18,728	3,756	911
Bone, right	6,756	6,184	....	6,927	6,496	5,922
Plate, right	34,875	16,603	35,901	46,616	18,103	10,486
Lean right	13,189	10,064	....	17,706	10,740	6,548
Fat, right	18,346	3,390	....	25,650	4,110	1,023
Bone, right	3,124	3,066	....	3,019	3,217	2,895
Rib, right	21,008	11,635	18,316	28,401	13,371	9,216
Lean, right	9,508	7,894	8,995	12,930	8,632	6,403
Fat, right	8,142	1,216	6,691	12,139	1,860	169
Bone, right	3,232	2,525	2,576	3,273	2,845	2,655
Loin, right	43,844	23,374	43,272	55,188	25,010	16,656
Lean right	20,810	14,862	....	25,070	15,720	12.100
Fat, right	19,162	5,094	....	26,362	5,817	1,222
Bone, right	3,892	3,253	....	3,570	3,422	3,293
Kidney, Fat, right	4,961	2,188	5,112	9,482	1,612	383
Flank, right	12,112	4,697	13,514	16,167	4,933	2,407
Lean, right	3,281	2,459	....	4,823	2,241	1,563
Fat, right	8,753	2,152	....	11,310	2,671	760
Bone, right	60	73	....	22	77	68
Rump, right	10,005	5,140	9,344	13,721	5,748	3,232
Lean, right	3,443	2,521	....	4,450	2,804	1,616
Fat, right	4,462	1,347	....	7,560	1,493	399
Bone, right	2,037	1,268	....	1,630	1,419	1,212
Round, right	34,172	25,274	40.959	39,746	28,102	23,013
Lean, right	21,471	19,651	....	25,698	22,307	18,857
Fat, right	9,529	2,689	....	10,733	2,508	1,263
Bone, right	3,172	2,932	....	3,223	3,176	2,939
Shank, right	6,922	4,865	*	6,434	4,865	4,202
Lean, right	1,873	1,864	....	2,190	1,772	1,422
Fat, right	1,105	289	....	837	98	95
Bone, right	3,941	2,665	....	3,398	2,986	2,656
Tail, total	882	730	857	778	700	553
Lean, total	312	292	....	362	328	218
Fat, total	132	24	....	48	40	24
Bone, total	354	354	....	370	332	290

*Weighed with round.

TABLE 10.—SLAUGHTER HOUSE WEIGHTS OF CARCASS PARTS (IN GRAMS).

Steer	513	502	509	501	512	500
Age	3 yr. 8 mo. 15 da.	3 yr. 8 mo. 19 da.	3 yr. 8 mo. 22 da.	3 yr. 11 mo.	3 yr. 11 mo. 21 da.	3 yr. 11 mo. 26 da.
Group	1	2	3	1	2	3
Head, total	13,287	12,902	10,642	14,702	13,233	11,824
Lean, total	3,690	3,386	2,556	4,004	3,266	2,930
Fat, total	1,294	438	264	606	706	380
Bone, total	7,865	9,078	7,822	9,962	9,139	8,514
Shin, right	8,748	7,032	6,523	9,018	7,437	7,355
Lean, right	4,639	3,719	3,769	4,670	3,928	4,199
Fat, right	1,039	355	238	1,223	461	316
Bone, right	3,060	2,970	2,523	3,085	3,037	2,805
Neck, right	1,944	1,585	1,635	1,841	1,600	1,660
Lean, right	987	944	925	833	800	874
Fat, right	616	188	171	558	175	198
Bone, right	357	462	537	447	620	589
Chuck, right	61,419	41,503	35,550	61,734	43,567	35,199
Lean, right	36,491	29,998	26,143	35,518	30,271	26,178
Fat, right	17,376	4,242	2,849	18,586	5,510	2,209
Bone, right	7,406	7,084	6,304	7,442	7,648	6,636
Plate, right	46,181	16,244	14,923	51,977	23,006	16,798
Lean right	18,269	10,056	9,499	18,093	11,581	10,651
Fat, right	24,127	3,412	2,896	30,290	7,474	3,052
Bone, right	3,623	2,713	2,512	3,487	3,827	3,094
Rib, right	27,830	13,821	11,725	27,783	14,527	10,321
Lean right	12,372	9,128	8,180	10,417	8,454	6,801
Fat, right	11,804	1,669	989	14,161	2,699	902
Bone, right	3,548	2,960	2,493	3,194	3,469	2,596
Loin, right	52,503	26,154	22,766	63,056	28,051	22,159
Lean, right	22,255	17,552	15,418	22,998	16,031	14,846
Fat, right	24,964	4,572	3,785	35,679	7,654	3,415
Bone, right	4,268	3,933	3,436	4,307	4,374	3,886
Kidney, Fat, right	7,245	1,458	788	9,772	2,370	1,216
Flank, right	15,560	4,390	3,558	18,768	5,502	4,586
Lean, right	4,237	2,331	2,117	4,544	1,847	2,805
Fat, right	11,254	1,998	1,383	14,146	3,571	1,697
Bone, right	96	82	50	47	67	81
Rump, right	11,288	5,243	5,142	13,018	6,870	5,041
Lean, right	3,609	2,998	2,631	3,816	3,054	2,471
Fat, right	5,932	1,052	1,054	7,297	2,188	1,058
Bone, right	1,732	1,181	1,430	1,841	1,632	1,494
Round, right	38,655	28,023	25,862	39,970	30,725	26,073
Lean, right	25,391	22,213	20,188	25,065	21,704	19,949
Fat, right	9,554	2,310	2,553	11,142	4,970	2,468
Bone, right	3,522	3,352	3,010	3,632	3,913	3,559
Shank, right	6,245	5,077	4,639	6,381	5,071	4,657
Lean, right	1,813	1,815	1,708	1,837	1,717	1,548
Fat, right	1,408	293	176	980	247	185
Bone, right	3,029	2,989	2,749	3,564	3,078	2,875
Tail, total	675	893	774	854	875	842
Lean, total	304	384	324	496	366	406
Fat, total	102	42	68	118	74	68
Bone, total	297	441	386	304	416	386

Table 11.—Distribution of Carcass and Offal Parts.

Steer	556	554	555	557	552	548
Age	3 mo.	3 mo.	3 mo.	5 mo. 17 da.	5 mo. 7 da.	5 mo. 9 da.
Group	1	2	3	1	2	3
Live weight	111,489	87,456	84,725	204,934	116,491	99,255
Warm empty weight	98,133	78,071	71,078	172,797	99,349	85,988
Percent empty weight to live weight	88.020	89.269	83.893	84.318	85.285	86.633
Percent carcass to live weight	54.188	57.319	53.626	53.710	52.998	54.388
Percent carcass to empty weight	61.563	64.210	63.923	63.700	62.143	62.780
Percent carcass + offal fat to live weight	55.446	58.055	54.172	57.008	54.530	54.232
Percent carcass + offal fat to empty weight	62.992	65.034	64.573	67.610	63.938	63.762
Percent offal fat to empty weight	1.429	0.825	0.650	3.910	1.796	0.983
Percent hide and hair to empty weight	10.510	9.479	9.257	8.160	10.601	9.720
Percent blood to empty weight	6.241	5.353	6.372	5.181	5.253	5.353
Percent heart market to empty weight	0.531	0.429	0.443	0.537	0.565	0.497
Percent lungs and trachea to empty weight	1.295	1.162	1.318	1.141	1.103	1.261
Percent brain and spinal cord to empty weight	0.406	0.506	0.497	0.319	0.469	0.612
Percent stomach to empty weight	2.013	1.547	1.882	2.512	1.951	2.192
Percent intestines to empty weight	2.745	2.660	3.437	2.370	2.802	2.932
Cm. intestines per kilo empty weight	34.83	37.17	34.61	22.03	31.41	39.03
Percent of liver to empty weight	1.793	1.494	1.745	1.838	1.189	1.284
Percent gall bladder and gall to empty weight	0.025	0.029	0.011	0.086	0.055	0.040
Percent of kidneys to empty weight	0.344	0.679	0.618	0.376	0.318	0.411
Percent spleen to empty weight	0.306	0.259	0.235	0.281	0.286	0.250
Percent pancreas to empty weight	0.098	0.097	0.149	0.130	0.102	0.099

Table 12.—Distribution of Carcass and Offal Parts.

Steer	547	550	558	541	538	540
Age	8 mo. 5 da.	8 mo. 14 da.	8 mo. 12 da.	10 mo. 22 da.	10 mo. 26 da.	11 mo. 2 da.
Group	1	2	3	1	2	3
Live weight	206,175	147,202	108,191	323,836	180,930	158,131
Warm empty weight	171,448	121,112	89,999	288,297	158,911	137,726
Percent empty weight to live weight	83.157	82.277	83.185	89.025	87.830	87.096
Percent carcass to live weight	54.167	50.459	51.085	58.594	53.658	55.226
Percent carcass to empty weight	65.138	61.328	61.411	65.817	61.093	63.408
Percent carcass + offal fat to live weight	56.048	52.232	51.851	61.786	55.566	56.685
Percent carcass + offal fat to empty weight	67.401	63.483	62.332	69.403	63.266	65.083
Percent offal fat to empty weight	2.262	2.155	0.921	3.586	2.172	1.675
Percent hide and hair to empty weight	8.526	8.620	9.042	9.219	9.654	9.435
Percent blood to empty weight	5.081	5.846	5.185	4.325	4.543	5.059
Percent heart market to empty weight	0.450	0.459	0.562	0.377	0.549	0.489
Percent lungs and trachea to empty weight	1.090	1.205	1.234	0.828	1.148	1.090
Percent brain and spinal cord to empty weight	0.268	0.366	0.578	0.197	0.306	0.372
Percent stomach to empty weight	3.027	3.165	2.833	2.732	2.845	2.827
Percent intestines to empty weight	2.610	2.992	2.908	1.819	2.294	2.366
Cm. intestines per kilo empty weight	20.78	27.87	34.43	14.08	25.19	23.83
Percent of liver to empty weight	1.663	1.645	1.502	1.329	1.245	1.157
Percent gall bladder and gall to empty weight	0.080	0.097	0.031	0.095	0.096	0.060
Percent of kidneys to empty weight	0.262	0.313	0.353	0.223	0.306	0.264
Percent spleen to empty weight	0.228	0.240	0.214	0.207	0.208	0.240
Percent pancreas to empty weight	0.117	0.165	0.170	0.135	0.131	0.131

TABLE 13.—DISTRIBUTION OF CARCASS AND OFFAL PARTS.

Steer	505	503	532	531	504	523	525
Age	10 mo. 18 da.	11 mo. 11 da.	1 yr. 5 mo. 20 da.	1 yr. 6 mo. 12 da.	1 yr. 8 mo. 26 da.	2 yr. 2 mo. 6 da.	2 yr. 2 mo. 8 da.
Group	1	2	1	3	1	2	3
Live weight	313,317	270,566	517,093	212,466	526,164	380,880	305,112
Warm empty weight	274,357	236,429	459,025	192,005	475,854	337,803	265,587
Percent empty weight to live weight	87.565	87.383	88.770	90.370	90.438	88.690	87.046
Percent carcass to live weight	56.445	54.048	60.459	56.015	58.235	57.708	54.265
Percent carcass to empty weight	64.460	61.852	68.107	61.984	64.391	65.067	62.341
Percent carcass + offal fat to live weight	60.524	56.778	65.042	57.379	63.006	59.786	55.891
Percent carcass + offal fat to empty weight	69.119	64.976	73.270	63.494	69.667	67.410	64.209
Percent offal fat to empty weight	4.659	3.124	5.162	1.510	5.276	2.343	1.868
Percent hide and hair to empty weight	8.393	9.779	7.404	8.694	8.646	9.798	10.472
Percent blood to empty weight	5.034	5.523	4.085	4.925	4.414	4.525	5.126
Percent heart market to empty weight	0.385	0.529	0.448	0.527	0.343	0.437	0.440
Percent lungs and trachea to empty weight	0.910	1.078	0.843	0.997	0.762	0.998	0.624
Percent brain and spinal cord to empty weight	0.196	0.282	0.140	0.298	0.152	0.236	0.268
Percent stomach to empty weight	3.214	2.439	2.373	2.783	2.694	2.766	3.332
Percent intestines to empty weight	1.768	2.003	1.291	1.921	2.002	1.547	2.244
Cm. intestines per kilo empty weight	16.26	20.93	11.69	19.21	10.88	13.80	....
Percent of liver to empty weight	1.452	1.542	1.240	1.148	0.999	0.967	1.083
Percent gall bladder and gall to empty weight	0.078	0.085	0.062	0.059	0.146	0.043	0.047
Percent of kidneys to empty weight	0.262	0.277	0.189	0.264	0.184	0.208	0.250
Percent spleen to empty weight	0.218	0.280	0.193	0.251	0.277	0.251	0.209
Percent pancreas to empty weight	0.109	0.122	0.131	0.155	0.062	0.089	0.057

TABLE 14.—DISTRIBUTION OF CARCASS AND OFFAL PARTS.

Steer	515	507	529	527	526	524
Age	2 yr. 9 mo. 19 da.	2 yr. 9 mo. 16 da.	3 yr. 2 mo. 21 da.	3 yr. 3 mo. 15 da.	3 yr. 4 mo.	3 yr. 4 mo. 13 da.
Group	1	2	1	1	2	3
Live weight	743,361	457,155	690,704	842,841	479,846	362,260
Warm empty weight	671,917	418,896	637,507	786,005	427,995	322,234
Percent empty weight to live weight	90.389	91.631	92.298	93.257	89.194	88.951
Percent carcass to live weight	61.489	60.490	65.687	70.423	61.176	58.075
Percent carcass to empty weight	68.028	66.015	71.169	75.515	68.587	65.289
Percent carcass + offal fat to live weight	65.509	62.964	71.342	76.179	63.583	59.458
Percent carcass + offal fat to empty weight	72.474	68.714	77.295	81.688	71.286	66.843
Percent offal fat to empty weight	4.447	2.699	6.126	6.173	2.699	1.554
Percent hide and hair to empty weight	7.433	8.229	7.148	5.883	8.349	9.339
Percent blood to empty weight	4.161	4.850	3.612	3.484	4.429	5.282
Percent heart market to empty weight	0.396	0.492	0.321	0.413	0.391	0.492
Percent lungs and trachea to empty weight	0.544	0.900	0.670	0.550	0.887	1.072
Percent brain and spinal cord to empty weight	0.108	0.178	0.110	0.089	0.154	0.235
Percent stomach to empty weight	1.960	2.297	1.898	1.316	2.567	2.512
Percent intestines to empty weight	1.015	1.343	0.830	0.642	0.966	1.240
Cm. intestines per kilo empty weight	6.99	9.46	6.05	6.28	10.37	11.35
Percent of liver to empty weight	0.890	0.904	0.843	0.728	0.825	0.937
Percent gall bladder and gall to empty weight	0.057	0.031	0.044	0.019	0.054	0.092
Percent of kidneys to empty weight	0.159	0.180	0.158	0.158	0.215	0.238
Percent spleen to empty weight	0.221	0.270	0.165	0.156	0.194	0.235
Percent pancreas to empty weight	0.063	0.055	0.129	0.108	0.116	0.135

TABLE 15.—DISTRIBUTION OF CARCASS AND OFFAL PARTS.

Steer	513	502	509	501	512	500
Age	3 yr. 8 mo. 15 da.	3 yr. 8 mo. 19 da.	3 yr. 8 mo. 22 da.	3 yr. 11 mo.	3 yr. 11 mo. 21 da.	3 yr. 11 mo. 26 da.
Group	1	2	3	1	2	3
Live weight	853,007	506,878	439,814	883,480	548,050	457,786
Warm empty weight	771,142	444,424	391,461	814,914	493,877	407,833
Percent empty weight to live weight	90.403	87.679	89.006	92.239	90.115	89.088
Percent carcass to live weight	65.317	60.284	60.342	68.953	61.796	59.358
Percent carcass to empty weight	72.252	68.756	67.795	74.755	68.575	66.628
Percent carcass + offal fat to live weight	71.621	62.528	62.598	73.325	64.981	62.185
Percent carcass + offal fat to empty weight	79.224	71.315	70.330	79.494	72.109	69.801
Percent offal fat to empty weight	6.973	2.560	2.535	4.740	3.534	3.173
Percent hide and hair to empty weight	5.873	8.901	9.609	6.147	8.356	8.812
Percent blood to empty weight	3.330	4.439	4.672	3.523	4.895	5.215
Percent heart market to empty weight	0.300	0.438	0.424	0.272	0.396	0.360
Percent lungs and trachea to empty weight	0.630	0.832	0.839	0.471	0.786	0.919
Percent brain and spinal cord to empty weight	0.097	0.180	0.189	0.093	0.135	0.204
Percent stomach to empty weight	1.744	2.438	2.516	1.741	2.245	2.696
Percent intestines to empty weight	0.761	0.934	0.994	0.598	1.078	1.112
Cm. intestines per kilo empty weight	7.18	10.16	10.62	5.95	11.23	10.62
Percent of liver to empty weight	0.768	0.836	0.990	0.756	0.894	1.136
Percent gall bladder and gall to empty weight	0.016	0.075	0.057	0.033	0.061	0.074
Percent of kidneys to empty weight	0.132	0.189	0.198	0.127	0.217	0.250
Percent spleen to empty weight	0.144	0.207	0.333	0.145	0.254	0.258
Percent pancreas to empty weight	0.113	0.131	0.144	0.103	0.149	0.153

TABLE 16.—MAIN DIVISIONS OF EMPTY ANIMAL AND LOSS ON COOLING.

Steer	556	554	555	557	552	548
Age	3 mo.	3 mo.	3 mo.	5 mo. 17 da.	5 mo. 7 da.	5 mo. 9 da.
Group	1	2	3	1	2	3
Weights of parts in grams						
Warm empty weight	98,133	78,071	71,078	172,797	99,349	85,988
Carcass	60,414	50,129	45,435	110,071	61,738	53,983
Offal fat	1,402	644	462	6,757	1,784	845
Hide and hair	10,314	7,400	6,580	14,100	10,532	8,358
Head, tail, feet, etc	6,813	6,203	5,653	10,591	8,081	7,463
Blood	6,124	4,197	4,529	8,952	5,219	4,603
Organs	11,488	8,419	8,489	19,831	10,701	9,645
Loss on cooling	1,422	300	23	724	716	1,658
Percent of parts to warm empty weight						
Carcass	61.563	64.210	63.923	63.700	62.143	62.780
Offal fat	1.429	0.825	0.650	3.910	1.796	0.983
Hide and hair	10.510	9.479	9.257	8.160	10.601	9.720
Head, tail, feet, etc	6.943	7.945	7.953	6.129	8.134	8.679
Blood	6.241	5.353	6.372	5.181	5.253	5.353
Organs	11.707	10.784	11.943	11.476	10.771	11.217
Loss on cooling	1.449	0.384	0.032	0.419	0.721	1.928

TABLES 17, 18, 19.—MAIN DIVISIONS OF EMPTY ANIMAL AND LOSS ON COOLING.

Steer	547	550	558	541	538	540
Age	8 mo. 5 da.	8 mo. 14 da.	8 mo. 12 da.	10 mo. 22 da.	10 mo. 26 da.	11 mo 2 da.
Group	1	2	3	1	2	3
Weights of parts in grams						
Warm empty weight	171,448	121,112	89,999	288,297	158,911	137,726
Carcass	111,678	74,276	55,269	189,748	97,084	87,329
Offal fat	3,879	2,610	829	10,337	3,452	2,307
Hide and hair	14,618	10,440	8,138	26,576	15,342	12,994
Head, tail, feet, etc	11,802	8,969	8,289	13,781	9,921	9,005
Blood	8,711	7,080	4,666	12,470	7,219	6,967
Organs	19,822	15,084	11,128	28,319	17,879	15,662
Loss on cooling	72	1,377	929	8,054	4,648	5,941
Percent of parts to warm empty weight						
Carcass	65.138	61.328	61.411	65.817	61.093	63.408
Offal fat	2.262	2.155	0.921	3.586	2.172	1.675
Hide and hair	8.526	8.620	9.042	9.219	9.654	9.435
Head, tail, feet, etc	6.884	7.406	9.210	4.780	6.243	6.538
Blood	5.081	5.846	5.185	4.325	4.543	5.059
Organs	11.562	12.455	12.365	9.823	11.251	11.372
Loss on cooling	0.042	1.137	1.032	2.794	2.925	4.314

Steer	505	503	532	531	504	523	525
Age	10 mo. 18 da.	11 mo. 11 da.	1 yr. 5 mo. 20 da.	1 yr. 6 mo. 12 da.	1 yr. 8 mo. 26 da.	2 yr. 2 mo. 6 da.	2 yr. 2 mo. 8 da.
Group	1	2	1	3	1	2	3
Weights of parts in grams							
Warm empty weight	274,357	236,429	459,025	192,005	475,854	337,803	265,587
Carcass	176,851	146,236	312,629	119,012	306,409	219,798	165,570
Offal fat	12,781	7,385	23,697	2,899	25,105	7,915	4,961
Hide and hair	23,026	23,120	33,988	16,693	41,144	33,097	27,813
Head, tail, feet., etc	13,377	15,218	20,120	11,718	21,024	23,460	16,701
Blood	13,810	13,058	18,752	9,457	21,005	15,287	13,614
Organs	28,033	25,676	39,809	20,313	45,006	32,570	26,676
Loss on cooling	5,398	3,164	10,030	12.701	7,208	5,676	10,252
Percent of parts to warm empty weight							
Carcass	64.460	61.852	68.107	61.984	64.391	65.067	62.341
Offal fat	4.659	3.124	5.162	1.510	5.276	2.343	1.868
Hide and hair	8.393	9.779	7.404	8.694	8.646	9.798	10.472
Head, tail, feet, etc	4.876	6.437	4.383	6.103	4.418	6.945	6.288
Blood	5.034	5.523	4.085	4.925	4.414	4.525	5.126
Organs	10.218	10.860	8.673	10.579	9.458	9.642	10.044
Loss on cooling	1.968	1.338	2.185	6.615	1.515	1.680	3.860

Steer	515	507	529	527	526	524
Age	2 yr. 9 mo. 19 da.	2 yr. 9 mo. 16 da.	3 yr. 2 mo. 21 da.	3 yr. 3 mo. 15 da.	3 yr. 4 mo.	3 yr. 4 mo. 13 da.
Group	1	2	1	1	2	3
Weights of parts in grams						
Warm empty weight	671,917	418,896	637,507	786,005	427,995	322,234
Carcass	457,088	276,534	453,705	593,554	293,550	210,384
Offal fat	29,877	11,307	39,056	48,517	11,551	5,007
Hide and hair	49,943	34,473	45,567	46,240	35,732	30,092
Head, tail, feet, etc	28,764	23,193	26,124	25,599	22,957	21,467
Blood	27,856	20,316	23,028	27,382	18,957	17,019
Organs	51,173	36,207	43,425	47,812	35,360	30,837
Loss on cooling	27,216	16,866	12,031	12,363	9,888	7,428
Percent of parts to warm empty weight						
Carcass	68.028	66.015	71.169	75.515	68.587	65.289
Offal fat	4.447	2.699	6.126	6.173	2.699	1.554
Hide and hair	7.433	8.229	7.148	5.883	8.349	9.339
Head, tail, feet, etc	4.281	5.537	4.098	3.257	5.364	6.662
Blood	4.161	4.850	3.612	3.484	4.429	5.282
Organs	7.616	8.643	6.812	6.083	8.262	9.570
Loss on cooling	4.051	4.026	1.887	1.573	2.310	2.305

TABLE 20.—MAIN DIVISIONS OF EMPTY ANIMAL AND LOSS ON COOLING.

Steer	513	502	509	501	512	500
Age	3 yr. 8 mo. 15 da.	3 yr. 8 mo. 19 da.	3 yr. 8 mo. 22 da.	3 yr. 11 mo.	3 yr. 11 mo. 21 da.	3 yr. 11 mo. 26 da.
Group	1	2	3	1	2	3
Weights of parts in grams						
Warm empty weight	771,142	444,424	391,461	814.914	493,877	407,833
Carcass	557,162	305,566	265,391	609,185	338,675	271,732
Offal fat	53,771	11,377	9,922	38,625	17,454	12,940
Hide and hair	45,286	39,556	37,614	50,090	41,268	35,938
Head, tail, feet, etc	27,336	26,278	20,423	30.523	25,833	22,814
Blood	25,680	19,728	18,291	28,710	24,176	21,269
Organs	48,968	36,679	33,938	47,332	40,410	36,998
Loss on cooling	13,067	3,968	4,097	11,976	5,864	6,624
Percent of parts to warm empty weight						
Carcass	72.252	68.756	67.795	74.755	68.575	66.628
Offal fat	6.973	2.560	2.535	4.740	3.534	3.173
Hide and hair	5.873	8.901	9.609	6.147	8.356	8.812
Head, tail, feet, etc	3.545	5.913	5.217	3.746	5.231	5.594
Blood	3.330	4.439	4.672	3.523	4.895	5.215
Organs	6.350	8.253	8.670	5.808	8.182	9.072
Loss on cooling	1.694	0.893	1.047	1.470	1.187	1.624

TABLE 21.—PROPORTION OF CUTS TO EMPTY WEIGHT AND TO CARCASS.

Steer	556	554	555	557	552	548
Age	3 mo.	3 mo.	3 mo.	5 mo. 17 da.	5 mo. 7 da.	5 mo. 9 da.
Group	1	2	3	1	2	3
Warm empty weight	98,133	78,071	71,078	172,797	99,349	85,988
Weight of carcass	60,570	50,908	45,342	111,842	62,316	53,416
Percent forequarters to empty weight	31.459	33.549	33.977	32.967	32.256	32.432
Percent forequarters to carcass	50.969	51.450	53.262	50.934	51.425	52.209
Percent hindquarters to empty weight	30.263	31.658	29.815	31.757	30.468	29.688
Percent hindquarters to carcass	49.031	48.550	46.738	49.065	48.575	47.791
Percent shins to empty weight	3.597	3.761	4.606	2.853	3.422	3.703
Percent shins to carcass	5.828	5.767	7.221	4.408	5.456	5.961
Percent of neck to empty weight	1.054	1.061	1.413	0.890	0.862	1.226
Percent of neck to carcass	1.707	1.626	1.214	1.375	1.374	1.973
Percent chucks to empty weight	15.489	17.277	16.497	15.148	15.805	15.970
Percent chucks to carcass	25.095	26.489	25.861	23.404	25.197	25.708
Percent of plates to empty weight	6.212	5.751	5.929	7.800	5.919	5.873
Percent of plates to carcass	10.064	8.820	9.294	12.051	9.436	9.454
Percent ribs to empty weight	5.065	5.492	5.388	6.107	6.281	5.610
Percent ribs to carcass	8.205	8.423	8.447	9.435	10.013	9.031
Percent of loin to to empty weight	10.249	10.473	8.728	10.842	10.361	8.987
Percent loin to carcass	16.606	16.060	13.683	16.750	16.519	14.468
Percent kidney fat + kidney to empty weight	0.772	0.986	0.801	2.244	0.821	0.741
Percent kidney fat + kidney to carcass	1.251	1.512	1.255	3.466	1.309	1.193
Percent flanks to empty weight	1.769	1.365	1.432	2.510	1.882	1.465
Percent flanks to carcass	2.866	2.094	2.245	3.879	3.001	2.359
Percent rumps to empty weight	1.887	2.283	1.978	2.059	1.987	1.886
Percent rumps to carcass	3.058	3.500	3.101	3.181	3.168	3.037
Percent rounds to empty weight	12.444	12.973	12.944	11.678	12.542	13.516
Percent rounds to carcass	20.162	19.893	20.290	18.043	19.995	21.758
Percent shanks to empty weight	3.012	3.574	3.683	2.390	2.877	3.035
Percent shanks to carcass	4.880	5.480	5.774	3.691	4.586	4.886
Percent head to empty weight	3.402	3.708	3.986	3.249	4.086	4.690
Percent tail to empty weight	0.175	0.256	0.172	0.192	0.239	0.171

TABLE 22.—PROPORTION OF CUTS TO EMPTY WEIGHT AND TO CARCASS.

Steer	547	550	558	541	538	540
Age	8 mo. 5 da.	8 mo. 14 da.	8 mo. 12 da.	10 mo. 22 da.	10 mo. 26 da.	11 mo. 2 da.
Group	1	2	3	1	2	3
Warm empty weight	171,448	121,112	89,999	288,297	158,911	137,726
Weight of carcass	112,544	75,552	56.020	188,760	100,450	84,850
Percent forequarters to empty weight	32.326	31.696	31.309	32.263	31.969	31.374
Percent forequarters to carcass	49.245	50.810	50.300	49.276	50.574	50.925
Percent hindquarters to empty weight	33.317	30.686	30.963	33.211	31.243	30.234
Percent hindquarters to carcass	50.755	49.190	49.700	50.724	49.426	49.075
Percent shins to empty weight	2.901	3.222	3.789	2.575	3.021	3.235
Percent shins to carcass	4.420	5.165	6.087	3.933	4.778	5.252
Percent of neck to empty weight	0.612	0.745	0.762	1.041	1.077	1.001
Percent of neck to carcass	.933	1.194	1.225	1.589	1.704	1.624
Percent chucks to empty weight	16.217	16.451	16.794	15.805	16.407	15.630
Percent chucks to carcass	24.705	26.371	26.980	24.139	25.955	25.369
Percent of plates to empty weight	6.771	6.184	4.567	7.052	6.444	6.352
Percent of plates to carcass	10.314	9.914	7.337	10.770	10.194	10.310
Percent ribs to empty weight	5.753	5.094	5.289	5.987	4.891	4.964
Percent ribs to carcass	8.766	8.167	8.497	9.144	7.737	8.057
Percent of loin to empty weight	12.100	11.295	9.687	12.371	11.273	11.331
Percent loin to carcass	18.434	18.107	15.562	18.895	17.834	18.392
Percent kidney fat + kidney to empty weight	1.213	0.937	0.604	2.324	0.698	0.759
Percent kidney fat + kidney to carcass	1.848	1.502	0.971	3.550	1.104	1.232
Percent flanks to empty weight	2.703	1.818	1.278	2.584	1.805	1.413
Percent flanks to carcass	4.118	2.915	2.053	3.947	2.855	2.293
Percent rumps to empty weight	1.786	1.949	1.924	1.918	1.807	1.888
Percent rumps to carcass	2.721	3.124	3.092	2.930	2.859	3.064
Percent rounds to empty weight	12.681	12.205	13.829	11.838	12.956	12.060
Percent rounds to carcass	19.319	19.565	22.217	18.081	20.496	19.576
Percent shanks to empty weight	2.666	2.480	3.416	2.110	2.651	2.628
Percent shanks to carcass	4.061	3.976	5.487	3.223	4.193	4.266
Percent head to empty weight	3.768	4.218	5.293	2.407	3.260	3.447
Percent tail to empty weight	0.170	0.154	0.109	0.132	0.144	0.158

TABLE 23.—PROPORTION OF CUTS TO EMPTY WEIGHT AND TO CARCASS.

Steer	505	503	532	531	504	523	525
Age	10 mo. 18 da.	11 mo. 11 da.	1 yr. 5 mo. 20 da.	1 yr. 6 mo. 12 da.	1 yr. 8 mo. 26 da.	2 yr. 2 mo. 6 da.	2 yr. 2 mo. 8 da.
Group	1	2	1	3	1	2	3
Warm empty weight	274,357	236,429	459,025	192,005	475,854	337,803	265,587
Weight of carcass	177,932	148,805	312,808	118,224	315,362	219,798	165,570
Percent forequarters to empty weight	33.049	31.680	34.684	30.919	32.187	33.223	32.535
Percent forequarters to carcass	50.959	50.334	50.897	50.215	48.566	51.060	52.188
Percent hindquarters to empty weight	31.805	31.260	33.462	30.654	34.087	31.844	29.806
Percent hindquarters to carcass	49.041	49.688	49.103	49.785	51.434	48.940	47.812
Percent shins to empty weight	2.699	2.817	2.938	3.236	2.574	2.925	3.259
Percent shins to carcass	4.162	4.476	4.311	5.256	3.883	4.496	5.228
Percent of neck to empty weight	0.761	0.980	0.643	1.346	0.646	0.824	1.169
Percent of neck to carcass	1.173	1.558	0.944	2.186	0.974	1.266	1.875
Percent chucks to empty weight	16.006	15.921	16.682	15.940	14.561	17.109	15.532
Percent chucks to carcass	24.680	25.296	24.480	25.888	21.972	26.295	24.915
Percent of plates to empty weight	7.248	6.412	8.051	5.711	7.946	7.102	6.443
Percent of plates to carcass	11.176	10.188	11.815	9.276	11.990	10.915	10.335
Percent ribs to empty weight	6.274	5.604	6.310	4.670	6.424	5.182	6.125
Percent ribs to carcass	9.674	8.904	9.260	7.584	9.694	7.965	9.825
Percent of loin to empty weight	11.388	11.399	11.924	10.042	12.239	11.156	9.971
Percent loin to carcass	17.560	18.111	17.497	16.310	18.468	17.147	15.994
Percent kidney fat + kidney to empty weight	2.360	1.176	2.745	0.642	2.580	1.129	0.724
Percent kidney fat + kidney to carcass	3.637	1.869	4.029	1.042	3.893	1.735	1.161
Percent flanks to empty weight	2.672	1.971	2.916	1.305	3.480	2.247	1.956
Percent flanks to carcass	4.120	3.132	4.279	2.120	5.251	3.453	3.138
Percent rumps to empty weight	2.031	1.815	2.261	1.857	2.787	2.147	2.166
Percent rumps to carcass	3.132	2.884	3.318	3.016	4.205	3.300	3.474
Percent rounds to empty weight	11.212	12.350	10.895	13.905	10.926	12.796	12.684
Percent rounds to carcass	17.288	19.623	15.988	22.583	16.486	19.666	20.345
Percent shanks to empty weight	2.103	2.574	2.040	2.767	2.025	2.294	2.277
Percent shanks to carcass	3.243	4.090	2.994	4.493	3.055	3.525	3.653
Percent head to empty weight	2.543	3.519	2.290	3.256	2.319	2.915	3.214
Percent tail to empty weight	0.190	0.163	0.147	0.146	0.145	0.186	0.176

TABLE 24.—PROPORTION OF CUTS TO EMPTY WEIGHT AND TO CARCASS.

Steer	515	507	529	527	526	524
Age	2 yr. 9 mo. 19 da.	2 yr. 9 mo. 16 da.	3 yr. 2 mo. 21 da.	3 yr. 3 mo. 15 da.	3 yr. 4 mo.	3 yr. 4 mo. 13 da.
Group	1	2	1	1	2	3
Warm empty weight	671,917	418,896	637,507	786,005	427,995	322,234
Wt. of carcass	457,088	276,534	448,276	578,092	293,550	210,384
Percent forequarters to empty weight	34.470	34.650	34.959	37.576	35.476	34.011
Percent forequarters to carcass	50.671	52.488	49.717	51.090	51.723	52.093
Percent hindquarters to empty weight	33.557	31.365	35.358	35.972	33.112	31.278
Percent hindquarters to carcass	49.329	47.512	50.283	48.910	48.277	47.907
Percent shins to empty weight	2.491	3.014	2.596	2.245	3.172	3.310
Percent shins to carcass	3.662	4.566	3.692	3.053	4.625	5.070
Percent of neck to empty weight	0.681	0.769	0.498	0.466	0.847	0.914
Percent of neck to carcass	1.001	1.165	0.708	0.634	1.235	1.400
Percent chucks to empty weight	14.675	17.408	14.856	15.776	16.779	17.525
Percent chucks to carcass	21.572	26.369	21.128	21.450	24.463	26.842
Percent of plates to empty weight	10.381	7.927	11.263	11.862	8.459	6.508
Percent of plates to carcass	15.260	12.008	16.017	16.128	12.334	9.968
Percent ribs to empty weight	6.253	5.555	5.746	7.227	6.248	5.720
Percent of loin to empty weight	9.192	8.415	8.172	9.826	9.110	8.761
Percent ribs to carcass	13.050	11.160	13.575	14.043	11.687	10.338
Percent loin to carcass	19.184	16.905	19.306	19.093	17.040	15.834
Percent kidney fat + kidney to empty weight	1.635	1.224	1.762	2.571	0.969	1.762
Percent kidney fat + kidney to carcass	2.404	1.854	2.505	3.496	1.412	2.699
Percent flanks to empty weight	3.605	2.243	4.240	4.114	2.305	1.494
Percent flanks to carcass	5.300	3.397	6.029	5.593	3.361	2.288
Percent rumps to empty weight	2.978	2.454	2.931	3.491	2.686	2.006
Percent rumps to carcass	4.378	3.717	4.169	4.747	3.916	3.072
Percent rounds to empty weight	10.171	12.067	12.850	10.113	13.132	14.283
Percent rounds to carcass	14.952	18.279	18.274	13.751	19.146	21.877
Percent shanks to empty weight	2.060	2.323	....	1.637	2.273	2.608
Percent shanks to carcass	3.029	3.519	....	2.226	3.315	3.995
Percent head to empty weight	2.213	2.835	2.078	1.633	2.720	3.387
Percent tail to empty weight	0.131	0.174	0.134	0.099	0.164	0.172

TABLE 25.—PROPORTION OF CUTS TO EMPTY WEIGHT AND TO CARCASS.

Steer	513	502	509	501	512	500
Age	3 yr. 8 mo. 15 da.	3 yr. 8 mo. 19 da.	3 yr. 8 mo. 22 da.	3 yr. 11 mo.	3 yr. 11 mo. 21 da.	3 yr. 11 mo. 26 da.
Group	1	2	3	1	2	3
Warm empty weight	771,142	444,424	391,461	814,914	493,877	407,833
Weight of carcass	557,034	306,838	267,176	607,658	338,872	371,250
Percent forequarters to empty weight	37.976	36.143	35.971	37.391	36.531	34.963
Percent forequarters to carcass	52.573	52.349	52.704	50.144	53.240	52.568
Percent hindquarters to empty weight	34.259	32.899	32.280	37.176	32.084	31.547
Percent hindquarters to carcass	47.427	47.651	47.296	49.856	46.760	47.432
Percent shins to empty weight	2.269	3.165	3.333	2.213	3.012	3.607
Percent shins to carcass	3.141	4.584	4.883	2.968	4.389	5.423
Percent of neck to empty weight	0.504	0.713	0.835	0.452	0.648	0.814
Percent of neck to carcass	0.698	1.033	1.224	0.606	0.944	1.224
Percent chucks to empty weight	15.929	18.677	18.163	15.151	17.643	17.261
Percent chucks to carcass	22.052	27.052	26.612	20.319	25.713	25.953
Percent of plates to empty weight	11.977	7.310	7.624	12.756	9.316	8.238
Percent of plates to carcass	16.581	10.588	11.171	17.107	13.578	12.386
Percent ribs to empty weight	7.218	6.220	5.990	6.819	5.883	5.061
Percent ribs to carcass	9.992	9.009	8.777	9.144	8.574	7.610
Percent of loin to empty weight	13.617	11.770	11.631	15.476	11.360	10.867
Percent loin to carcass	18.851	17.047	17.042	20.754	16.556	16.338
Percent kidney fat + kidney to empty weight	2.011	0.845	0.600	2.526	1.177	0.846
Percent kidney fat + kidney to carcass	2.783	1.223	0.880	3.387	1.716	1.272
Percent flanks to empty weight	4.036	1.976	1.818	4.606	2.228	2.249
Percent flanks to carcass	5.587	2.861	2.663	6.177	3.247	3.381
Percent rumps to empty weight	2.928	2.359	2.627	3.195	2.782	2.472
Percent rumps to carcass	4.053	3.417	3.849	4.285	4.055	3.717
Percent rounds to empty weight	10.025	12.611	13.213	9.810	12.442	12.786
Percent rounds to carcass	13.879	18.266	19.360	13.139	18.134	19.224
Percent shanks to empty weight	1.620	2.285	2.370	1.566	2.054	2.284
Percent shanks to carcass	2.242	3.309	3.473	2.100	2.993	3.434
Percent head to empty weight	1.723	2.903	2.719	1.804	2.679	2.899
Percent tail to empty weight	0.087	0.201	0.198	0.105	0.177	0.206

TABLE 26.—DISTRIBUTION OF LEAN, FAT AND BONE.

Steer	556	554	555	557	552	548
Age	3 mo.	3 mo.	3 mo.	5 mo. 17 da.	5 mo. 7 da.	5 mo. 9 da.
Group	1	2	3	1	2	3
Proportion of lean, fat and bone in empty animal						
Percent skeleton	21.148	24.090	23.364	17.020	21.443	22.973
Percent lean flesh	41.874	43.747	44.125	39.045	42.579	43.234
Percent fatty tissue (excl. offal fat)	4.168	3.440	2.334	13.634	5.552	3.114
Percent total fatty tissue	5.596	4.265	2.994	17.545	7.348	4.097
Percent offal and kidney fats to total fatty tissue	33.176	26.547	27.820	32.935	31.288	32.047
Proportion of lean, fat and bone in carcass						
Percent skeleton	25.527	27.595	27.343	19.392	24.485	26.535
Percent lean flesh	66.551	65.628	67.372	59.293	66.436	67.631
Percent fatty tissue	6.535	4.997	3.357	20.384	6.357	4.793
Percent kidney fat to fatty tissue in carcass	10.611	9.434	8.541	14.159	9.601	11.094

TABLE 27.—DISTRIBUTION OF LEAN, FAT AND BONE.

Steer	547	550	558	541	538	540
Age	8 mo. 5 da.	8 mo. 14 da.	8 mo. 12 da.	10 mo. 22 da.	10 mo. 26 da.	11 mo. 2 da.
Group	1	2	3	1	2	3
Proportion of lean, fat and bone in empty animal						
Percent skeleton	16.096	19.271	23.734	13.301	17.502	18.126
Percent lean flesh	44.646	42.361	42.627	42.917	43.496	42.316
Percent fatty tissue (excl. offal fat)	10.642	6.916	3.558	12.988	7.139	6.189
Percent total fatty tissue	12.905	9.071	4.479	16.574	9.311	7.864
Percent offal and kidney fats to total fatty tissue	24.899	30.639	26.172	34.309	27.534	27.597
Proportion of lean, fat and bone in carcass						
Percent skeleton	17.789	22.864	27.504	14.958	20.418	21.638
Percent lean flesh	65.640	65.534	65.973	64.728	67.616	67.595
Percent fatty tissue	15.485	10.573	5.159	19.565	10.999	9.636
Percent kidney fat to fatty tissue in carcass	9.353	9.464	7.820	16.399	5.630	8.341

TABLE 28.—DISTRIBUTION OF LEAN, FAT AND BONE.

Steer	505	503	532	531	504	523
Age	10 mo. 18 da.	11 mo. 11 da.	1 yr. 5 mo. 20 da.	1 yr. 6 mo. 12 da.	1 yr. 8 mo. 26 da.	2 yr. 2 mo. 6 da.
Group	1	2	1	3	1	2
Proportion of lean, fat and bone in empty animal						
Percent skeleton	13.758	17.393	13.557	17.218	12.082	15.161
Percent lean flesh	41.235	41.941	41.765	43.867	38.281	44.821
Percent fatty tissue (excl. offal fat)	13.662	8.861	16.111	5.158	18.905	9.008
Percent total fatty tissue	18.321	11.985	21.274	6.668	24.181	11.351
Percent offal and kidney fats to total fatty tissue	36.875	33.566	36.283	28.314	31.726	38.754
Proportion of lean, fat and bone in carcass						
Percent skeleton	15.978	20.207	15.544	20.686	13.696	17.332
Percent lean flesh	62.622	65.374	60.392	70.033	56.850	67.631
Percent fatty tissue	20.576	13.467	23.177	8.130	28.300	13.687
Percent kidney fat to fatty tissue in carcass	15.716	10.609	16.185	7.553	12.773	10.338

TABLE 29.—DISTRIBUTION OF LEAN, FAT AND BONE.

Steer	525	515	507	527	526	524
Age	2 yr. 2 mo. 8 da.	2 yr. 9 mo. 19 da.	2 yr. 9 mo. 16 da.	3 yr. 3 mo. 15 da.	3 yr. 4 mo.	3 yr. 4 mo. 13 da.
Group	3	1	2	1	2	3
Proportion of lean, fat and bone in empty animal						
Percent skeleton	16.230	11.555	15.532	9.382	16.138	19.740
Percent lean flesh	44.504	33.109	44.151	34.603	44.777	46.354
Percent fatty tissue (excl. offal fat)	6.201	26.547	10.631	31.891	11.653	4.242
Percent total fatty tissue	8.069	30.994	13.331	38.063	14.352	5.795
Percent offal and kidney fats to total fatty tissue	29.021	19.111	26.085	22.555	24.054	30.913
Proportion of lean, fat and bone in carcass						
Percent skeleton	19.522	13.009	18.004	9.943	18.316	23.425
Percent lean flesh	69.778	47.947	65.918	46.403	64.347	69.762
Percent fatty tissue	9.625	38.452	15.607	43.137	16.696	6.134
Percent kidney fat to fatty tissue in carcass	7.894	5.645	10.139	7.605	6.578	5.936

TABLE 30.—DISTRIBUTION OF LEAN, FAT AND BONE.

Steer	513	502	509	501	512	500
Age	3 yr. 8 mo. 15 da.	3 yr. 8 mo. 19 da.	3 yr. 8 mo. 22 da.	3 yr. 11 mo.	3 yr. 11 mo. 21 da.	3 yr. 11 mo. 26 da.
Group	1	2	3	1	2	3
Proportion of lean, fat and bone in empty animal						
Percent skeleton	9.991	16.302	16.570	9.891	16.285	17.509
Percent lean flesh	34.251	46.190	47.013	31.915	40.983	45.112
Percent fatty tissue (excl. offal fat)	30.090	9.806	8.710	35.389	15.271	8.307
Percent total fatty tissue	37.063	12.365	11.245	40.129	18.805	11.480
Percent offal and kidney fats to total fatty tissue	23.884	26.009	26.121	17.788	23.897	32.832
Proportion of lean, fat and bone in carcass						
Percent skeleton	11.001	18.072	18.747	10.218	18.688	20.361
Percent lean flesh	46.698	65.672	67.804	42.060	58.658	66.597
Percent fatty tissue	41.405	14.046	12.637	47.340	22.025	12.325
Percent kidney fat to fatty tissue in carcass	6.283	6.766	4.668	6.794	6.351	7.274

TABLE 31.—DISTRIBUTION OF LEAN FLESH IN THE ANIMAL.

Steer	556	554	555	557	552	548
Age	3 mo.	3 mo.	3 mo.	5 mo. 17 da.	5 mo. 7 da.	5 mo. 9 da.
Group	1	2	3	1	2	3
Weight of lean in animal	20,546	17,077	15,681	33,734	21,151	18,588
Percent of total lean in head	1.708	1.956	2.442	1.553	1.882	2.679
Percent of total lean in shin	4.088	3.777	5.287	3.436	4.085	3.954
Percent of total lean in neck	1.674	1.353	1.830	1.254	1.258	1.544
Percent of total lean in chuck	26.599	28.079	27.409	26.036	26.538	27.077
Percent of total lean in plate	10.201	8.637	9.317	10.998	8.922	8.904
Percent of total lean in rib	7.841	8.532	8.010	9.444	9.432	8.446
Percent of total lean in loin	16.884	17.017	14.725	17.362	16.628	15.246
Percent of total lean in flank	2.915	2.249	2.889	3.311	2.823	2.394
Percent of total lean in rump	2.667	2.653	2.557	2.413	2.605	2.609
Percent of total lean in round	23.051	23.183	22.722	22.173	23.238	24.769
Percent of total lean in shank	2.176	2.342	2.659	1.862	2.340	2.233
Percent of total lean in tail	0.195	0.223	0.153	0.157	0.251	0.145

TABLE 32.—DISTRIBUTION OF LEAN FLESH IN THE ANIMAL.

Steer	547	550	558	541	538	540
Age	8 mo. 5 da.	8 mo. 14 da.	8 mo. 12 da.	10 mo. 22 da.	10 mo. 26 da.	11 mo. 2 da.
Group	1	2	3	1	2	3
Weight of lean in animal	38.272	25,652	19,182	61,864	34,560	29,140
Percent of total lean in head	3.308	3.321	3.618	1.122	1.617	1.527
Percent of total lean in shin	3.601	3.863	4.056	3.115	3.464	4.005
Percent of total lean in neck	0.792	1.010	1.090	1.578	1.455	1.551
Percent of total lean in chuck	26.390	26.820	27.854	27.271	27.321	26.668
Percent of total lean in plate	9.338	9.450	7.226	10.159	9.251	9.602
Percent of total lean in rib	8.570	8.124	8.305	9.366	7.517	8.102
Percent of total lean in loin	17.736	17.683	15.541	18.925	18.420	18.360
Percent of total lean in flank	3.585	2.557	2.409	2.699	2.781	2.255
Percent of total lean in rump	1.934	2.460	2.414	2.227	2.257	2.622
Percent of total lean in round	22.330	22.844	25.190	21.822	23.617	23.089
Percent of total lean in shank	2.237	1.696	2.252	1.586	2.182	2.159
Percent of total lean in tail	0.180	0.172	0.047	0.129	0.119	0.062

TABLE 33.—DISTRIBUTION OF LEAN FLESH IN THE ANIMAL.

Steer	505	503	532	531	504	523	525
Age	10 mo. 18 da.	11 mo. 11 da.	1 yr. 5 mo. 20 da.	1 yr. 6 mo. 12 da.	1 yr. 8 mo. 26 da.	2 yr. 2 mo. 6 da.	2 yr. 2 mo. 8 da.
Group	1	2	1	3	1	2	3
Weight of lean in animal	56,566	49,580	95,857	42,113	91,081	75,704	59,099
Percent of total lean in head	1.321	1.743	1.297	1.555	1.458	1.651	1.758
Percent of total lean in shin	3.566	3.235	3.697	3.804	3.487	3.528	4.097
Percent of total lean in neck	1.133	1.105	0.875	2.208	0.927	1.246	1.734
Percent of total lean in chuck	28.068	28.318	28.167	27.364	25.353	28.695	26.405
Percent of total lean in plate	10.361	8.871	10.450	8.513	10.559	10.176	9.562
Percent of total lean in rib	9.988	9.008	9.053	7.449	10.159	7.947	9.870
Percent of total lean in loin	17.401	17.352	18.849	16.715	18.487	17.063	15.829
Percent of total lean in flank	3.380	2.985	3.061	2.044	4.148	3.010	2.883
Percent of total lean in rump	2.298	2.041	2.681	2.377	3.166	2.376	2.689
Percent of total lean in round	20.493	23.193	19.855	25.522	20.442	22.390	23.286
Percent of total lean in shank	1.801	1.999	1.850	2.306	1.692	1.749	1.736
Percent of total lean in tail	0.189	0.151	0.166	0.143	0.122	0.169	0.151

TABLE 34.—DISTRIBUTION OF LEAN FLESH IN THE ANIMAL.

Steer	515	507	529	527	526	524
Age	2 yr. 9 mo. 19 da.	2 yr. 9 mo. 16 da.	3 yr. 2 mo. 21 da.	3 yr. 3 mo. 15 da.	3 yr. 4 mo.	3 yr. 4 mo. 13 da.
Group	1	2	1	1	2	3
Weight of lean in animal	111,232	92,474	....	135,989	95,822	74,684
Percent of total lean in head	1.344	1.281	....	1.236	1.266	1.595
Percent of total lean in shin	3.436	3.805	....	3.214	3.866	3.523
Percent of total lean in neck	0.998	1.079	....	0.536	1.093	1.208
Percent of total lean in chuck	27.936	29.534	....	26.590	26.589	28.576
Percent of total lean in plate	11.857	10.883	....	13.020	11.208	8.768
Percent of total lean in rib	8.548	8.536	....	9.508	9.008	8.573
Percent of total lean in loin	18.709	16.072	....	18.435	16.405	16.201
Percent of total lean in flank	2.950	2.659	....	3.547	2.339	2.093
Percent of total lean in rump	3.095	2.726	....	3.272	2.926	2.164
Percent of total lean in round	19.303	21.250	....	18.897	23.280	25.249
Percent of total lean in shank	1.684	2.016	....	1.610	1.849	1.904
Percent of total lean in tail	0.140	0.158	....	0.133	0.171	0.146

TABLE 35.—DISTRIBUTION OF LEAN FLESH IN THE ANIMAL.

Steer	513	502	509	501	512	500
Age	3 yr. 8 mo. 15 da.	3 yr. 8 mo. 19 da.	3 yr. 8 mo. 22 da.	3 yr. 11 mo.	3 yr. 11 mo 21 da.	.3 yr. 11 mo 26 da.
Group	1	2	3	1	2	3
Weight of lean in animal	132,060	102,639	92,018	130,041	101,203	91,990
Percent of total lean in head	1.397	1.649	1.389	1.540	1.613	1.593
Percent of total lean in shin	3.513	3.623	4.096	3.591	3.881	4.565
Percent of total lean in neck	0.747	0.920	1.005	0.641	0.790	0.950
Percent of total lean in chuck	27.632	29.227	28.411	27.313	29.911	28.457
Percent of total lean in plate	13.834	9.797	10.323	13.913	11.443	11.578
Percent of total lean in rib	9.368	8.893	8.890	8.011	8.354	7.393
Percent of total lean in loin	16.852	17.101	16.755	17.685	15.840	16.139
Percent of total lean in flank	3.208	2.271	2.301	3.494	1.825	3.049
Percent of total lean in rump	2.733	2.921	2.859	2.934	3.018	2.686
Percent of total lean in round	19.227	21.642	21.939	19.275	21.446	21.686
Percent of total lean in shank	1.373	1.768	1.856	1.413	1.697	1.683
Percent of total lean in tail	0.115	0.187	0.176	0.191	0.181	0.221

TABLE 36.—DISTRIBUTION OF FAT FLESH IN THE ANIMAL.

Steer	556	554	555	557	552	548
Age	3 mo.	3 mo.	3 mo.	5 mo. 17 da.	5 mo. 7 da.	5 mo. 9 da.
Group	1	2	3	1	2	3
Weight of fat in animal	2,045	1,343	833	11,780	2,758	1,329
Percent of total fat in head	3.227	5.287	8.643	3.090	5.584	4.406
Percent of total fat in shin	3.961	6.031	8.523	1.647	2.538	3.809
Percent of total fat in neck	3.472	3.797	....	1.265	1.958	4.108
Percent of total fat in chuck	15.795	13.999	13.926	14.584	14.822	14.414
Percent of total fat in plate	7.628	9.308	5.042	15.017	10.442	9.783
Percent of total fat in rib	1.907	....	....	6.859	2.067	1.494
Percent of total fat in kidney fat	10.269	8.935	7.803	13.701	9.065	10.605
Percent of total fat in loin	20.049	15.934	16.447	18.981	18.891	14.339
Percent of total fat in flank	11.540	9.978	9.364	8.922	11.965	12.696
Percent of total fat in rump	3.619	5.436	4.442	4.049	4.061	2.689
Percent of total fat in round	16.773	19.360	22.569	10.747	16.461	19.417
Percent of total fat in shank	1.760	1.936	3.241	0.993	2.139	2.240
Percent of total fat in tail	....	....	....	0.144	....	....

TABLE 37.—DISTRIBUTION OF FAT FLESH IN THE ANIMAL.

Steer	547	550	558	541	538	540
Age	8 mo. 5 da.	8 mo. 14 da.	8 mo. 12 da.	10 mo. 22 da.	10 mo. 26 da.	11 mo. 2 da.
Group	1	2	3	1	2	3
Weight of fat in animal	9,123	4,188	1,601	18,722	5,672	4,262
Percent of total fat in head	4.428	4.585	9.744	1.229	2.468	4.036
Percent of total fat in shin	1.852	1.552	3.186	1.699	1.693	1.619
Percent of total fat in neck	1.261	0.955	1.249	0.977	2.891	0.469
Percent of total fat in chuck	14.250	17.383	16.802	11.804	18.212	17.500
Percent of total fat in plate	13.592	10.697	8.495	13.155	14.616	15.157
Percent of total fat in rib	6.040	2.865	1.749	6.500	3.755	3.801
Percent of total fat in kidney fat	8.933	9.026	7.058	16.174	5.483	8.001
Percent of total fat in loin	21.769	25.478	18.738	21.600	20.804	27.076
Percent of total fat in flank	10.161	10.029	6.996	10.880	9.362	7.297
Percent of total fat in rump	4.253	4.776	3.248	4.535	4.725	5.115
Percent of total fat in round	11.783	11.270	20.112	10.293	15.004	9.503
Percent of total fat in shank	1.622	1.337	2.623	1.010	0.846	0.375
Percent of total fat in tail	0.055	0.048	....	0.144	0.141	0.047

TABLE 38.—DISTRIBUTION OF FAT FLESH IN THE ANIMAL.

Steer	505	503	532	531	504	523	525
Age	10 mo. 18 da.	11 mo. 11 da.	1 yr. 5 mo. 20 da.	1 yr. 6 mo. 12 da.	1 yr. 8 mo. 26 da.	2 yr. 2 mo. 6 da.	2 yr. 2 mo. 8 da.
Group	1	2	1	3	1	2	3
Weight of fat in animal	18,742	10 475	36.977	4,952	44,980	15,214	8,234
Percent of total fat in head	2.172	4.229	1.901	2.827	0.720	1.006	3.085
Percent of total fat in shin	1.094	1.403	1.266	2.262	1.670	1.729	2.417
Percent of total fat in neck	0.720	1.728	0.749	2.383	0.518	0.381	1.421
Percent of total fat in chuck	13.440	11.437	13.484	17.750	12.750	16.012	14.149
Percent of total fat in plate	13.798	14.081	15.299	12.298	15.480	13.330	14.258
Percent of total fat in rib	7.043	4.010	8.375	3.413	7.526	5.002	4.032
Percent of total fat in kidney fat	15.351	10.148	15.867	7.330	12.672	10.221	7.639
Percent of total fat in loin	20.163	27.427	20.221	22.859	20.387	20.954	22.820
Percent of total fat in flank	9.273	7.561	10.033	7.512	9.931	9.734	10.347
Percent of total fat in rump	4.877	5.642	3.946	5.089	5.645	5.981	5.927
Percent of total fat in round	11.050	10.587	8.200	15.044	10.914	14.973	11.914
Percent of total fat in shank	0.864	1.632	0.592	1.111	1.716	0.552	1.846
Percent of total fat in tail	0.155	0.115	0.068	0.121	0.071	0.125	0.146

TABLE 39.—DISTRIBUTION OF FAT FLESH IN THE ANIMAL.

Steer	515	507	529	527	526	524
Age	2 yr. 9 mo. 19 da.	2 yr. 9 mo. 16 da.	3 yr. 2 mo. 21 da.	3 yr. 3 mo. 15 da.	3 yr. 4 mo.	3 yr. 4 mo. 13 da.
Group	1	2	1	1	2	3
Weight of fat in animal	89,188	22,267	....	125,332	24,937	6,834
Percent of total fat in head	1.393	3.036	....	0.497	1.648	5.414
Percent of total fat in shin	1.724	1.159	....	1.022	0.995	2.766
Percent of total fat in neck	0.748	0.804	....	0.481	1.335	0.556
Percent of total fat in chuck	12.576	12.471	....	14.943	15.062	13.330
Percent of total fat in plate	20.570	15.224	....	20.466	16.482	14.969
Percent of total fat in rib	9.129	5.461	....	9.685	7.459	2.473
Percent of total fat in kidney fat	5.562	9.826	....	7.566	6.464	5.604
Percent of total fat in loin	21.485	22.877	....	21.034	23.327	17.881
Percent of total fat in flank	9.814	9.665	....	9.024	10.711	11.121
Percent of total fat in rump	5.003	6.099	....	6.032	5.987	5.838
Percent of total fat in round	10.684	12.076	....	8.564	10.057	18.481
Percent of total fat in shank	1.239	1.298	....	0.668	0.393	1.390
Percent of total fat in tail	0.074	0.054	....	0.019	0.080	0.176

TABLE 40.—DISTRIBUTION OF FAT FLESH IN THE ANIMAL.

Steer	513	502	509	501	512	500
Age	3 yr. 8 mo. 15 da.	3 yr. 8 mo. 19 da.	3 yr. 8 mo. 22 da.	3 yr. 11 mo.	3 yr. 11 mo. 21 da.	3 yr. 11 mo 26 da.
Group	1	2	3	1	2	3
Weight of fat in animal	116,017	21,789	17,048	144,196	37,709	16,940
Percent of total fat in head	0.558	1.005	0.774	0.210	0.936	1.122
Percent of total fat in shin	0.896	1.629	1.396	0.848	1.223	1.865
Percent of total fat in neck	0.531	0.863	1.003	0.387	0.464	1.169
Percent of total fat in chuck	14.977	19.469	16.712	12.890	14.612	13.040
Percent of total fat in plate	20.796	15.659	16.987	21.006	19.820	18.017
Percent of total fat in rib	10.174	7.660	5.801	9.821	7.157	5.325
Percent of total fat in kidney fat	6.245	6.691	4.622	6.777	6.285	7.178
Percent of total fat in loin	21.518	20.983	22.202	24.743	20.298	20.159
Percent of total fat in flank	9.700	9.170	8.112	9.810	9.470	10.018
Percent of total fat in rump	5.113	4.828	6.183	5.060	5.802	6.246
Percent of total fat in round	8.235	10.602	14.975	7.727	13.180	14.569
Percent of total fat in shank	1.214	1.345	1.032	0.680	0.655	1.092
Percent of total fat in tail	0.044	0.096	0.199	0.041	0.098	0.201

TABLE 41.—DISTRIBUTION OF SKELETON IN THE ANIMAL.

Steer	556	554	555	557	552	548
Age	3 mo.	3 mo.	3 mo.	5 mo. 17 da.	5 mo. 7 da.	5 mo. 9 da.
Group	1	2	3	1	2	3
Wt. of skeleton in animal	10,277	9,404	8,304	14,705	10,652	9,877
Percent of total skeleton in head	12.576	11.857	11.911	13.499	14.327	15.136
Percent of total skeleton in shin	8.201	7.784	8.755	7.637	7.276	8.019
Percent of total skeleton in neck	0.964	1.414	2.589	1.401	1.070	1.934
Percent of total skeleton in chuck	17.029	18.429	17.438	17.769	17.275	16.442
Percent of total skeleton in plate	7.450	6.678	7.286	8.439	7.041	7.502
Percent of total skeleton in rib	7.931	7.199	7.563	8.745	9.783	8.170
Percent of total skeleton in loin	10.929	9.932	7.611	8.426	10.290	8.363
Percent of total skeleton in flank	0.154	0.117	0.157	0.054	0.075	0.162
Percent of total skeleton in rump	2.930	3.892	3.047	3.264	3.004	2.885
Percent of total skeleton in round	9.512	9.050	9.948	9.133	7.633	9.608
Percent of total skeleton in shank	9.406	10.198	10.261	8.875	8.177	8.667
Percent of total skeleton in tail	0.443	0.670	0.446	0.660	0.620	0.476
Percent of total skeleton in feet	12.475	12.777	12.988	12.098	13.430	12.635

TABLE 42.—DISTRIBUTION OF SKELETON IN THE ANIMAL.

Steer	547	550	558	541	538	540
Age	8 mo. 5 da.	8 mo. 14 da.	8 mo. 12 da.	10 mo. 22 da.	10 mo. 26 da.	11 mo. 2 da.
Group	1	2	3	1	2	3
Weight of skeleton in animal	13,798	11,670	10,680	19,173	13,906	12,482
Percent of total skeleton in head	11.893	13.539	14.869	14.082	14.389	14.749
Percent of total skeleton in shin	6.726	7.506	8.090	7.683	7.939	7.819
Percent of total skeleton in neck	0.790	1.260	0.964	1.763	1.438	1.706
Percent of total skeleton in chuck	17.763	19.974	18.024	17.264	18.021	17.906
Percent of total skeleton in plate	7.023	6.530	5.075	7.380	7.637	7.395
Percent of total skeleton in rib	7.871	7.455	7.097	8.246	7.745	7.307
Percent of total skeleton in loin	11.349	10.557	10.009	10.212	9.694	10.215
Percent of total skeleton in flank	0.072	0.069	0.037	0.089	0.072	0.064
Percent of total skeleton in rump	2.754	2.999	3.174	2.754	2.632	2.492
Percent of total skeleton in round	9.016	8.997	9.803	8.475	9.190	9.414
Percent of total skeleton in shank	9.182	8.663	9.860	9.764	9.377	9.229
Percent of total skeleton in tail	0.522	0.403	0.375	0.537	0.489	0.553
Percent of total skeleton in feet	15.038	12.048	12.622	11.751	11.384	11.152

TABLE 43.—DISTRIBUTION OF SKELETON IN THE ANIMAL.

Steer	505	503	532	531	504	523	525
Age	10 mo. 18 da.	11 mo. 11 da.	1 yr. 5 mo. 20 da.	1 yr. 6 mo. 12 da.	1 yr. 8 mo. 26 da.	2 yr. 2 mo. 6 da.	2 yr. 2 mo. 8 da.
Group	1	2	1	3	1	2	3
Weight of skeleton in animal	18,873	20,561	31,116	16,539	28,747	25,608	21,552
Percent of total skeleton in head	12.876	14.377	11.014	14.198	13.988	14.128	13.943
Percent of total skeleton in shin	7.837	7.626	8.687	8.427	7.528	7.791	7.800
Percent of total skeleton in neck	1.399	2.091	1.189	1.555	1.579	1.476	1.847
Percent of total skeleton in chuck	18.529	16.458	19.723	16.891	17.859	17.631	17.757
Percent of total skeleton in plate	7.831	8.151	8.642	7.550	7.823	7.474	7.865
Percent of total skeleton in rib	8.457	8.224	8.391	6.897	8.857	7.505	9.020
Percent of total skeleton in loin	10.263	9.323	10.037	8.572	10.175	10.391	9.113
Percent of total skeleton in flank	0.106	0.204	0.161	0.151	0.129	0.105	0.148
Percent of total skeleton in rump	2.930	2.553	3.667	3.206	4.223	3.456	3.577
Percent of total skeletonin round	8.997	9.377	9.037	11.010	8.363	9.040	9.387
Percent of total skeleton in shank	8.970	9.114	8.597	9.716	8.589	9.513	8.473
Percent of total skeleton in tail	0.636	0.462	0.427	0.448	0.550	0.617	0.520
Percent of total skeleton in feet	11.169	12.037	10.429	11.379	10.338	10.872	10.551

TABLE 44.—DISTRIBUTION OF SKELETON IN THE ANIMAL.

Steer	515	507	529	527	526	524
Age	2 yr. 9 mo. 19 da.	2 yr. 9 mo. 16 da.	3 yr. 2 mo. 21 da.	3 yr. 3 mo. 15 da.	3 yr. 4 mo.	3 yr. 4 mo 13 da.
Group	1	2	1	1	2	3
Weight of skeleton in animal	38,821	32,531	....	36,872	34,535	31,805
Percent of total skeleton in head	12.725	13.249	....	11.491	12.790	12.621
Percent of total skeleton in shin	7.751	7.716	....	8.597	8.166	7.782
Percent of total skeleton in neck	1.309	1.282	....	1.378	1.231	1.654
Percent of total skeleton in chuck	17.403	19.010	....	18.787	18.810	18.620
Percent of total skeleton in plate	8.047	9.425	....	8.188	9.315	9.102
Percent of total skeleton in rib	8.325	7.762	....	8.877	8.238	8.348
Percent of total skeleton in loin	10.026	10.000	....	9.682	9.909	10.354
Percent of total skeleton in flank	0.155	0.224	....	0.060	0.223	0.214
Percent of total skeleton in rump	5.247	3.898	....	4.421	4.109	3.811
Percent of total skeleton in round	8.171	9.013	....	8.741	9.196	9.241
Percent of total skeleton in shank	10.152	8.192	....	9.216	8.646	8.351
Percent of total skeleton in tail	0.456	0.544	....	0.502	0.481	0.456
Percent of total skeleton in feet	10.234	9.686	....	10.092	8.887	9.448

TABLE 45.—DISTRIBUTION OF SKELETON IN THE ANIMAL.

Steer	513	502	509	501	512	500
Age	3 yr. 8 mo. 15 da.	3 yr. 8 mo. 19 da.	3 yr. 8 mo. 22 da.	3 yr. 11 mo.	3 yr. 11 mo. 21 da.	3 yr. 11 mo. 26 da.
Group	1	2	3	1	2	3
Weight of skeleton in animal	38,521	36,226	32,433	40,301	40,214	35,704
Percent of total skeleton in head	10.799	13.220	12.715	12.980	12.018	12.539
Percent of total skeleton in shin	7.944	8.199	7.779	7.655	7.552	7.856
Percent of total skeleton in neck	0.927	1.275	1.656	1.109	1.542	1.650
Percent of total skeleton in chuck	19.226	19.555	19.437	18.466	19.018	18.586
Percent of total skeleton in plate	9.405	7.489	7.745	8.652	9.517	8.666
Percent of total skeleton in rib	9.211	8.171	7.687	7.925	8.626	7.271
Percent of total skeleton in loin	11.080	10.857	10.594	10.687	10.877	10.884
Percent of total skeleton in flank	0.249	0.226	0.154	0.117	0.167	0.227
Percent of total skeleton in rump	4.496	3.260	4.409	4.568	4.058	4.184
Percent of total skeleton in round	9.143	9.253	9.281	9.012	9.730	9.968
Percent of total skeleton in shank	7.863	8.251	8.476	8.843	7.654	8.052
Percent of total skeleton in tail	0.387	0.610	0.595	0.377	0.517	0.541
Percent of total skeleton in feet	9.862	9.637	9.472	9.608	8.723	9.576

Table 46.—Proportion of Lean, Fat, and Bone in Cuts of the Carcass.

Steer	556	554	555	557	552	548
Age	3 mo.	3 mo.	3 mo.	5 mo. 17 da.	5 mo. 7 da.	5 mo. 9 da.
Group	1	2	3	1	2	3
Percent of lean in shin	47.592	43.937	50.641	47.018	50.824	46.168
Percent of fat in shin	4.589	5.518	4.337	7.870	4.118	3.204
Percent of bone in shin	48.215	49.864	44.411	45.558	45.588	49.749
Percent of lean in neck	66.538	55.797	57.171	55.007	62.150	54.459
Percent of fat in neck	13.733	12.319	....	19.376	12.617	10.436
Percent of bone in neck	19.342	32.126	42.829	26.788	26.636	36.243
Percent of lean in chuck	71.908	71.100	73.307	67.107	71.494	73.303
Percent of fat in chuck	4.250	2.788	1.979	13.127	5.210	2.811
Percent of bone in chuck	23.250	25.697	24.697	19.965	23.437	23.653
Percent of lean in plate	68.766	65.702	69.340	55.053	64.184	65.545
Percent of fat in plate	5.118	5.568	1.993	26.250	9.796	5.188
Percent of bone in plate	25.361	27.973	28.714	18.415	25.510	29.347
Percent of lean in rib	64.829	67.957	65.587	60.387	63.942	65.091
Percent of fat in rib	1.569	....	....	15.315	1.827	0.829
Percent of bone in rib	33.119	31.576	32.794	24.375	33.397	33.458
Percent of lean in loin	68.980	71.086	74.436	62.528	68.331	73.344
Percent of fat in loin	8.153	5.235	4.417	23.871	10.122	4.969
Percent of bone in loin	22.549	22.847	20.374	13.227	21.294	21.377
Percent of lean in flank	69.009	72.045	82.514	51.498	63.850	70.635
Percent of fat in flank	27.189	25.141	14.208	48.456	35.294	26.984
Percent of bone in flank	1.843	2.064	2.368	0.369	0.856	2.540
Percent of lean in rump	59.179	50.842	57.041	45.756	55.826	59.803
Percent of fat in rump	7.997	8.193	5.263	26.813	11.348	4.439
Percent of bone in rump	32.829	41.077	35.989	26.981	32.421	35 142
Percent of lean in round	77.563	78.179	77.457	74.133	78.892	79.229
Percent of fat in round	5.617	5.134	4.087	12.547	7.287	4.474
Percent of bone in round	16.164	16.805	17.957	13.310	13.050	16.331
Percent of lean in shank	30.244	28.674	31.856	30.426	34.640	31.801
Percent of fat in shank	2.436	1.804	2.063	5.669	4.129	2.299
Percent of bone in shank	66.035	68.746	65.088	63.227	60.952	65.594

Table 47.—Proportion of Lean, Fat, and Bone in Cuts of the Carcass.

Steer	547	550	558	541	538	540
Age	8 mo. 5 da.	8 mo. 14 da.	8 mo. 12 da.	10 mo. 22 da.	10 mo. 26 da.	11 mo. 2 da
Group	1	2	3	1	2	3
Percent of lean in shin	55.408	50.794	45.630	51.913	49.875	52.379
Percent of fat in shin	6.795	3.332	2.991	8.567	4.000	3.097
Percent of bone in shin	37.314	44.900	50.674	39.682	46.000	43.806
Percent of lean in neck	57.714	57.428	60.933	65.067	58.762	65.602
Percent of fat in neck	21.905	8.869	5.831	12.200	19.159	2.993
Percent of bone in neck	20.762	32.594	30.029	22.533	23.364	30.914
Percent of lean in chuck	72.651	69.062	70.703	74.054	72.430	72.201
Percent of fat in chuck	9.351	7.308	3.560	9.701	7.924	6.931
Percent of bone in chuck	17.631	23.399	25.473	14.529	19.224	20.766
Percent of lean in plate	61.578	64.726	67.445	61.830	62.441	63.969
Percent of fat in plate	21.365	11.963	6.618	24.230	16.191	14.769
Percent of bone in plate	16.695	20.347	26.375	13.920	20.742	21.102
Percent of lean in rib	66.504	67.553	66.933	67.138	66.855	69.075
Percent of fat in rib	11.172	3.890	1.176	14.102	5.481	4.740
Percent of bone in rib	22.019	28.201	31.849	18.320	27.715	26.682
Percent of lean in loin	65.439	66.316	68.387	65.654	71.073	68.563
Percent of fat in loin	19.146	15.599	6.882	22.677	13.174	14.789
Percent of bone in loin	15.097	18.012	24.524	10.980	15.050	16.340
Percent of lean in flank	59.215	59.582	80.348	44.832	67.015	67.523
Percent of fat in flank	40.009	38.147	19.478	54.685	37.029	31.963
Percent of bone in flank	0.432	0.727	0.696	0.456	0.697	0.822
Percent of lean in rump	48.334	53.475	53.464	49.837	54.318	58.769
Percent of fat in rump	25.343	16.949	6.005	30.705	18.663	16.769
Percent of bone in rump	24.820	29.661	39.145	19.096	25.487	23.923
Percent of lean in round	78.613	79.286	77.647	79.109	79.289	81.011
Percent of fat in round	9.889	6.386	5.174	11.292	8.267	4.877
Percent of bone in round	11.443	14.206	16.825	9.522	12.415	14.148
Percent of lean in shank	37.462	28.961	28 107	32.249	35.802	34.751
Percent of fat in shank	6.477	3.728	2.733	6.213	2.279	0.884
Percent of bone in shank	55.449	67.310	68.510	61.538	61.918	63.646

TABLE 48.—PROPORTION OF LEAN, FAT, AND BONE IN CUTS OF THE CARCASS.

Steer	505	503	532	531	504	523	525
Age	10 mo. 18 da.	11 mo. 11 da.	1 yr. 5 mo. 20 da.	1 yr. 6 mo. 12 da.	1 yr. 8 mo. 26 da.	2 yr. 2 mo. 6 da.	2 yr. 2 mo. 8 da.
Group	1	2	1	3	1	2	3
Percent of lean in shin	54.469	48.168	52.566	51.561	51.870	54.058	55.938
Percent of fat in shin	5.536	4.414	6.942	3.605	12.265	5.323	4.598
Percent of bone in shin	39.941	47.087	40.092	44.834	35.342	40.376	38.840
Percent of lean in neck	61.398	47.282	56.843	71.981	54.948	67.693	66.044
Percent of fat in neck	12.931	15.617	18.767	9.133	15.169	4.170	7.539
Percent of bone in neck	25.287	37.101	25.068	19.892	29.557	27.175	25.644
Percent of lean in chuck	72.310	74.598	70.518	75.305	66.653	75.017	75.657
Percent of fat in chuck	11.472	6.365	13.022	5.744	16.554	8.430	5.648
Percent of bone in chuck	15.927	17.980	16.029	18.245	14.819	15.624	18.554
Percent of lean in plate	58.946	58.021	54.207	65.384	50.870	64.227	66.047
Percent of fat in plate	26.008	19.459	30.613	11.107	36.832	16.907	13.721
Percent of bone in plate	14.865	22.111	14.552	22.761	11.896	15.957	19.811
Percent of lean in rib	65.644	67.411	59.919	69.975	60.532	68.731	71.711
Percent of fat in rib	15.336	6.340	21.384	3.770	22.144	8.694	4.082
Percent of bone in rib	18.543	25.525	18.028	25.429	16.656	21.958	23.900
Percent of lean in loin	63.007	63.844	66.024	73.011	57.821	68.547	70.652
Percent of fat in loin	24.190	21.321	27.322	11.742	31.489	16.918	14.191
Percent of bone in loin	12.399	14.266	11.412	14.698	10.044	14.121	14.833
Percent of lean in flank	52.169	63.519	43.843	68.715	45.628	60.053	65.589
Percent of fat in flank	47.422	33.991	55.439	29.689	53.949	39.025	32.794
Percent of bone in flank	0.546	1.803	0.747	1.995	0.447	0.711	1.232
Percent of lean in rump	46.662	47.158	49.518	56.141	43.493	49.600	55.250
Percent of fat in rump	32.807	27.540	28.112	14.133	38.290	25.090	16.968
Percent of bone in rump	19.849	24.464	21.985	29.725	18.308	24.400	26.808
Percent of lean in round	75.371	78.760	76.110	80.515	71.625	78.425	81.708
Percent of fat in round	13.466	7.596	12.125	5.581	18.884	10.540	5.824
Percent of bone in round	11.040	13.205	11.245	13.634	9.248	10.711	12.011
Percent of lean in shank	35.321	32.567	37.868	36.559	31.991	34.177	33.929
Percent of fat in shank	5.615	5.619	4.677	2.071	16.027	2.168	5.026
Percent of bone in shank	58.683	61.584	57.134	60.467	51.256	62.881	60.384

TABLE 49.—PROPORTION OF LEAN, FAT, AND BONE IN CUTS OF THE CARCASS.

Steer	515	507	529	527	526	521
Age	2 yr. 9 mo. 19 da.	2 yr. 9 mo. 16 da.	3 yr. 2 mo. 21 da.	3 yr. 3 mo. 15 da.	3 yr. 4 mo.	3 yr. 4 mo 13 da.
Group	1	2	1	1	2	3
Percent of lean in shin	45.663	55.742	....	49.535	54.559	49.334
Percent of fat in shin	18.375	4.087	....	14.517	3.653	3.544
Percent of bone in shin	35.950	39.759	....	35.925	41.538	46.409
Percent of lean in neck	48.514	61.949	....	39.792	57.781	61.236
Percent of fat in neck	29.152	11.111	....	32.915	18.377	2.580
Percent of bone in neck	22.203	25.885	....	27.729	23.455	35.709
Percent of lean in chuck	63.029	74.907	....	58.273	70.957	75.584
Percent of fat in chuck	22.750	7.617	....	30.206	10.461	3.510
Percent of bone in chuck	13.704	16.961	....	11.172	18.092	20.973
Percent of lean in plate	37.818	60.616	....	37.983	59.327	62.445
Percent of fat in plate	52.605	20.418	....	55.024	22.703	9.756
Percent of bone in plate	8.958	18.467	....	6.476	17.771	27.608
Percent of lean in rib	45.259	67.847	49.110	45.527	64.558	69.477
Percent of fat in rib	38.757	10.451	36.531	42.742	13.911	1.834
Percent of bone in rib	15.385	21.702	14.064	11.524	21.277	28.809
Percent of lean in loin	47.464	63.583	....	45.427	62.855	72.646
Percent of fat in loin	43.705	21.793	....	47.768	23.259	7.337
Percent of bone in loin	8.877	13.917	....	6.469	13.683	19.771
Percent of lean in flank	27.089	52.353	....	29.832	45.429	64.936
Percent of fat in flank	72.267	45.816	....	69.957	54.146	31.575
Percent of bone in flank	0.495	1.554	....	0.136	1.561	2.825
Percent of lean in rump	34.413	49.047	....	32.432	48.782	50.000
Percent of fat in rump	44.598	26.206	....	55.098	25.974	12.345
Percent of bone in rump	20.360	24.669	....	11.880	24.687	37.500
Percent of lean in round	62.832	77.752	....	64.656	79.379	81.941
Percent of fat in round	27.885	10.639	....	27.004	8.925	5.488
Percent of bone in round	9.282	11.601	....	8.109	11.302	12.771
Percent of lean in shank	27.059	38.314	....	34.038	36.423	33.841
Percent of fat in shank	15.964	5.940	....	13.009	2.014	2.261
Percent of bone in shank	56.934	54.779	....	52.813	61.377	63.208

TABLE 50.—PROPORTION OF LEAN, FAT, AND BONE IN CUTS OF THE CARCASS.

Steer	513	502	509	501	512	500
Age	3 yr. 8 mo. 15 da.	3 yr. 8 mo. 19 da.	3 yr. 8 mo. 22 da.	3 yr. 11 mo.	3 yr. 11 mo. 21 da.	3 yr. 11 mo 26 da.
Group	1	2	3	1	2	3
Percent of lean in shin	53.029	52.887	57.780	51.785	52.817	57.090
Percent of fat in shin	11.900	5.048	3.649	13.562	6.199	4.297
Percent of bone in shin	34.979	42.235	38.679	34.154	40.836	38.138
Percent of lean in neck	50.772	59.557	56.575	45.247	50.000	52.651
Percent of fat in neck	31.687	11.861	10.459	30.310	10.938	11.928
Percent of bone in neck	18.364	29.148	32.844	24.280	38.750	35.482
Percent of lean in chuck	59.413	72.279	73.539	57.534	69.481	74.371
Percent of fat in chuck	28.291	10.221	8.014	30.106	12.647	6.276
Percent of bone in chuck	12.058	17.069	17.735	12.055	17.555	18.853
Percent of lean in plate	39.560	61.906	63.653	34.810	50.339	63.406
Percent of fat in plate	52.244	21.005	19.406	58.276	32.487	18.169
Percent of bone in plate	7.845	16.702	16.833	6.709	16.635	18.419
Percent of lean in rib	44.456	66.044	69.765	37.494	58.195	65.894
Percent of fat in rib	42.415	12.076	8.435	50.970	18.579	8.739
Percent of bone in rib	12.749	21.417	21.262	11.496	23.880	25.153
Percent of lean in loin	42.388	67.110	67.724	36.472	57.149	66.998
Percent of fat in loin	47.548	17.481	16.626	56.583	27.286	15.411
Percent of bone in loin	8.129	15.038	15.093	6.830	15.593	17.537
Percent of lean in flank	27.230	53.098	59.500	24.211	33.570	61.164
Percent of fat in flank	72.326	45.513	38.870	75.373	64.904	37.004
Percent of bone in flank	0.617	1.868	1.405	0.250	1.218	1.766
Percent of lean in rump	31.972	57.181	51.167	29.313	44.454	49.018
Percent of fat in rump	52.551	20.065	20.498	56.053	31.849	20.988
Percent of bone in rump	15.344	22.525	27.810	14.142	23.755	29.637
Percent of lean in round	65.686	79.267	78.060	62.710	70.640	76.512
Percent of fat in round	24.716	8.243	9.872	27.876	16.176	9.466
Percent of bone in round	9.111	11.962	11.639	9.087	12.736	13.650
Percent of lean in shank	29.031	35.749	36.818	28.789	33.859	33.240
Percent of fat in shank	22.546	5.771	3.794	15.358	4.871	3.973
Percent of bone in shank	48.503	58.873	59.258	55.853	60.698	61.735

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Studies In Animal Nutrition

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STUDIES IN ANIMAL NUTRITION

III. Changes in Chemical Composition on Different Planes of Nutrition.

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The changes experienced by beef cattle in form and weight and in proportions of carcass and offal when on different planes of nutrition were presented in previous bulletins†. The 31 representative animals slaughtered at various intervals from three groups were used (with one exception) for a study of the chemical composition of the various parts, organs, and cuts of beef.

GENERAL TREATMENT

For a general discussion of the treatment of the animals the previous bulletins must be consulted. The ration included milk for several months after birth, and timothy hay and grain were soon introduced. At weaning time the ration consisted of alfalfa hay and a grain mixture in the ratio of one to two. The grain consisted of six parts corn chop, three parts whole oats, and one part of old process linseed meal.

The animals were early divided into three groups. Group I was fed all it would eat of the ration. Group II was fed for maximum growth without permitting the laying on of much fat. Group III was fed for scanty or retarded growth. The Group II steers gained about a pound a day for the first two years while the Group III cattle gained but 0.69 pounds a day.

The animals were slaughtered at intervals and a series of weights and measurements were taken. The wholesale cuts were divided into lean flesh, fatty tissue, and bone and tendon. Various composites and individual samples were analyzed, there being a rather large number of samples for each animal.

METHODS OF PREPARATION OF SAMPLES

The samples of the soft tissues and parts were passed through a power grinder equipped with four sets of plates, each plate hav-

*Resigned September, 1918.

†C. Robert Moulton, P. F. Trowbridge, L. D. Haigh, Studies in Animal Nutrition. I. Changes in Form and Weight on Different Planes of Nutrition, Research Bulletin 43. II. Changes in Proportions of Carcass and Offal on Different Planes of Nutrition, Research Bulletin 54, Missouri Agricultural Experiment Station.

ing holes of a different size than the other. Samples were ground through the coarser plate and then through the next size. The samples well mixed and quartered down if necessary and then ground through a finer plate. The large samples were then quartered again and ground through the finest plate. Very homogeneous and fine samples were easily obtained in this manner. An especially difficult sample to make uniform was the respiratory system. The cartilaginous rings of the trachea would partly remain behind in the mill while the softer lungs were squeezed out past them. By means of a knife these rings were finely cut and mixed with the lungs. The hide sample was cut into thin strips with a knife, alternate strips being rejected in the larger samples. The strips were then cut into short lengths and ground through the mill already described. The grinding of the sample proceeded very solwly, but with repeated grindings the work advanced more rapidly and a final uniform and fine sample was obtained.

The work of preparing and grinding the samples proceeded as rapidly as possible until the samples were in a position where there was no danger of decomposition or change. The samples were kept in jars provided with rubber gaskets, glass tops, and metal clamps so that no loss of moisture could occur. They were kept in cold storage at a temperature just above freezing, so that they remained fresh for analysis.

The skeleton samples were ground through a Mann green bone grinder, mixed well and sampled. From this smaller samples were weighed out directly and rapidly, in triplicate, in tared procelain evaporating dishes. The size of the samples varied according to the coarseness or fineness of the bone. For finely ground samples 25 to 40 grams were considered sufficient while for coarse samples 100 grams or even more were sometimes taken. The dishes containing the weighed samples were at once placed in vacuum desiccators and dried to a constant weight within 25 or 30 milligrams. They were then extracted with ether in specially constructed Sohxlet extractors. The residue was saved, the triplicates combined, and the whole ground in a steel mill until fine enough to pass through a millimeter sieve. The sample was allowed to become air dry and saved for a complete analysis later.

Samples of horn and hoof were dried and reduced to a fairly fine state with a horseshoer's rasp. A drug mill was then used to reduce the material to a finer state.

METHODS OF ANALYSIS

The samples were analyzed for water, fat, nitrogen, ash and phosphorus, following in general official methods of the Association of Official Agricultural Chemists.

Glycogen, dextrose, and sarco-lactic acid and similar flesh acids were not determined. The formation of the acids in flesh progressively increases from the time of slaughter up to a maximum and then a decrease follows as decomposition takes place until neutrality and finally alkalinity is reached*. The glycogen† content varies considerably in different parts of the animal and decreases quite rapidly at ordinary temperatures through hydrolysis to dextrose. Through determination of the glycogen content of a number of animals it is certain that in beef flesh the amount of glycogen will seldom exceed one-half of one percent.

Water.—For this work the S. & S. extraction shells and glass tubes with hardened filter paper bottoms were filled about one-third full of ignited sea sand and then stuffed with fat-free absorbent cotton. In our later work cotton alone was used. The tubes were numbered consecutively, extracted with ether, dried *in vacuo* and weighed in glass stoppered weighing bottles. This was done previous to the slaughtering. A counterpoised weighing bottle was found very convenient as it obviated complications arising from a broken weighing bottle, the use of a new bottle and subsequent corrections of weights. Scheibler vacuum desiccators six inches in diameter with stopcocks in the lid were filled to the depth of an inch with C. P. sulphuric acid (sp. gr. 1.84). A brass gauze or porcelain plate was placed on the shelf of the desiccator and one-half inch above this supported by corks or rubber stoppers was a second gauze. Clean paper was placed on this. It was necessary to have the ground glass surfaces and stopcocks fit well. A lubricant of three parts of hard paraffin and five parts of yellow vaseline was prepared by melting together these ingredients and allowing the mixture to cool slowly. In cold weather a little more vaseline is used and in hot weather a little more paraffin to give the mixture the proper consistency.

The thoroughly mixed samples were placed in weighing bottles provided with short aluminum scoops and triplicate samples of three to five grams were weighed out. The cotton was removed from the extraction tube and placed in a flat-bottomed, shallow,

*Trowbridge, P. F. and Grindley, H. S., J. Amer. Chem. Soc. 28, (1906), 469.
†Trowbridge, P. F. and Francis, C. K., J. Ind. and Eng. Chem. 2 (1910), 21 and 215.

glazed porcelain dish and the sand was poured carefully into the dish. The meat sample was placed on the sand and the whole was carefully and thoroughly mixed and then returned to the tube by a steel spatula. The cotton was used to wipe every trace of the sample from the dish and spatula. A large sheet of glazed paper prevented loss of sand. The last of the unused cotton was placed in the top of the tube. Later when cotton alone was used, the mixing of the sample was greatly facilitated and the danger of loss of sand was entirely removed. The sand, or cotton, was used to separate the particles of the sample and so allow a more thorough drying and extraction. Otherwise the samples had to be ground and reextracted a second time. The triplicate samples were placed in separate desiccators in order to avoid a loss in case a desiccator was broken or acid spilled on the cones. The desiccators held 15 to 20 tubes. The desiccators when full were exhausted to a one-centimeter vacuum by means of a Geryk duplex vacuum pump. The desiccators were rotated carefully twice a day to mix the concentrated acid with the supernatant watery layer. After 24 to 48 hours or longer, as convenient, air was allowed to bubble slowly through a sulphuric acid tower into the desiccator until the vacuum was destroyed. The tubes were transferred to desiccators holding fresh acid and the drying was continued as before. The tubes were then transferred to glass stoppered weighing bottles and weighed in the weighing bottle. The drying was continued to constant weight as given in detail above.

Fat.—The dry tubes from the moisture determinations were extracted for 24 hours in Sohxlet extractors, using ether. They were partially dried in an electric oven at a low temperature and then dried in the vacuum desiccators as given in detail above. They were weighed as above and dried again to constant weight. Loss in weight is fat.

Nitrogen.—Nitrogen was determined by the Kjeldahl-Gunning-Arnold method. Triplicate samples were weighed out as in the fat determination and placed in S. & S. No. 595 filter papers and introduced into a 500-cc. Kjeldahl flask. For hide and hair 0.50 to 0.75 grams was used, for lean meat 1.00 to 1.25 grams, and for fat samples 2.50 to 3.50 grams. Other samples in accordance to the nitrogen content. Twenty-five cubic centimeters of C. P. concentrated sulphuric acid was used for the meats and 35 to 50 cc. for fats. About 0.7 grams of mercury was added and the digestion was made on a digestion frame. When the sample had ceased

foaming and was not pasty, 7 to 10 grams of potassium or sodium sulphate was added and the digestion was continued for one or two hours. The flasks were then cooled and the necks washed down with water. They were again digested for an hour or more. About 300 cc. of nitrogen-free water was added to the cool flasks also a piece of paraffin the size of a pea and a few small pieces of granulated zinc. Then 85 cc. of the alkali solution (100 cc. for fats) was added carefully, the flask was connected with a condenser, the contents were mixed, the flasks boiled for 40 minutes and the distillate caught in a wide-mouthed receiving flask containing the necessary amount of one-tenth normal hydrocholoric acid with some cochineal indicator. The above alkali solution was made by dissolving 40 pounds of Greenbank alkali and 375 grams of potassium sulphide in 30 liters of distilled water. For fats and other foaming materials 800-cc. Kjeldahl flasks were used.

Protein.—The protein was calculated by multiplying the nitrogen by the factor 6.25.

Ash.—Triplicate samples of ten to fifteen grams were weighed out as for fat and placed in numbered, tared porcelain crucibles. The samples were dried in ovens and then charred carefully. Later they were ashed over Fletcher burners, using a low heat and taking plenty of time. In this way fusion and loss of chlorides was prevented.

Phosphorus.—The crucibles from the ash determinations were leached with strong hydrochloric acid and a little nitric acid. The solutions were neutralized and ammonium nitrate was added. The phosphorus was precipitated to 65° C. with acid ammonium molybdate. The yellow phospho-molybdate was filtered off, washed, dissolved in ammonia and hot water and the phosphorus was reprecipitated with magnesia mixture. The precipitate was ignited strongly in a gasoline muffle and weighed as the pyrophosphate.

AIR DRY BONE SAMPLES

Moisture and Ash.—Two-gram samples were weighed out in tared porcelain crucibles and dried at 100 to 110° C. The difference in weight between crucible plus sample and dry weight of crucible plus sample gave the moisture. The samples were then ashed by igniting over Fletcher burners until practically free from carbon and the ignition was completed in a muffle at a dull red heat. A clear white ash was readily obtained by this means in a short time.

Nitrogen.—The nitrogen was determined as given in detail above using 0.5 gram samples.

Phosphorus.—The ash from the above determination was dissolved by digestion in hot, dilute nitric acid and the solution was made up to 250 cc. Aliquots of 25 cc. were taken and the phosphorus determined as given in detail above.

COMPOSITION OF SAMPLES

The percentage composition of each sample analyzed is shown in the Appendix in Tables 1 to 30 and the weights of the constituents in Tables 31 to 60. The detailed weights for the separate parts included in each sample can be found in Research Bulletin 54. The weight of the entire sample is shown in the tables listed above. From this data samples can be composited and the composition of various classes of tissues, parts of the animal, or the entire animal can be calculated. The tables include the analyses of 1061 samples from 30 different animals, or over 35 samples per animal.

The samples listed are mutually exclusive. For example the circulatory system for Steer 500 weighed 1.562 kilograms and had 48.451 percent water, 37.638 percent fat, and so on. This sample consisted of the large arteries and blood vessels in the thorax, the pericardium, adherent fat, and the ears of the heart. The lean heart itself exclusive of the ears formed a separate sample weighing 1.284 kilograms and having 77.544 percent of water, 3.559 percent of ether soluble material, and so on. Each system listed is exclusive of those parts which follow as separate samples which parts would ordinarily be considered as part of the system.

A few samples of horns, teeth or hoofs and dewclaws were lost or detsroyed before the analyses were completed. The composition of a similar sample was in such cases used to calculate the composition of the sample destroyed or lost. Full explanation of this is given at the foot of each table where such instances occur.

Since the plan of the experiment was slightly modified from time to time the number and content of the samples is not the same for all the animals. Consequently the samples can not all be compared directly. To facilitate comparison certain composited systems are presented in Tables 61 to 71 in the Appendix.

The Blood.—The composition of the blood is shown graphically in figure 1. The water content is close to 80 percent being about 82 percent during the first two years and 78 to 80 percent

from 3 years on. There is a tendency for the percentage of water to be in inverse order to the plane of nutrition, i. e., the higher the plane the lower the percentage of water. Fat was not found in the blood by the method used for this work.

The nitrogen content varies between 2.5 and 3.5 percent increasing with age and increased plane of nutrition, although there are a few exceptions to both rules. The ash content is close to

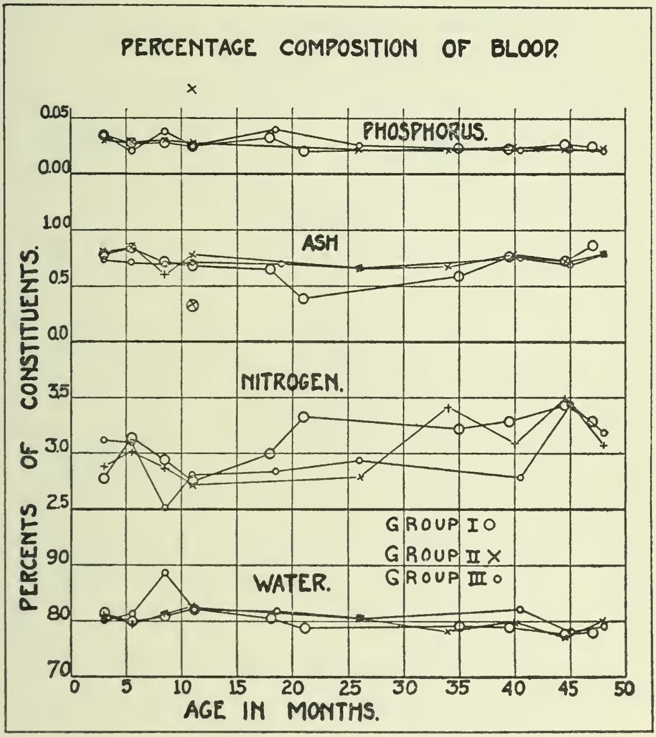

Fig. 1.—Composition of the blood of beef animals.

0.75 percent. It seems to be unaffected by age or plane of nutrition. The ash content of the blood of Steers 503, 504, and 505 is unusually low and probably is not normal. The phosphorus is 0.025 percent and is apparently unaffected by the plane of nutrition. It seems to be slightly less in the older animals than in the younger animals.

The Nervous System.—The composition of the central nervous system—the brain and spinal cord—is shown in figure 2. The water content is between 65 and 75 percent. It decreases slightly with

age and does not seem to be affected by the plane of nutrition. The fat—ether soluble material—is 10 to 20 percent of this sample. It increases with age and seems not to be affected by the plane of nutrition. The nitrogen content is low for animal tissue being about 1.7 percent. It seems to be independent of age or plane of nutrition. The ash varies from 1.4 to 1.9 percent, increasing with age

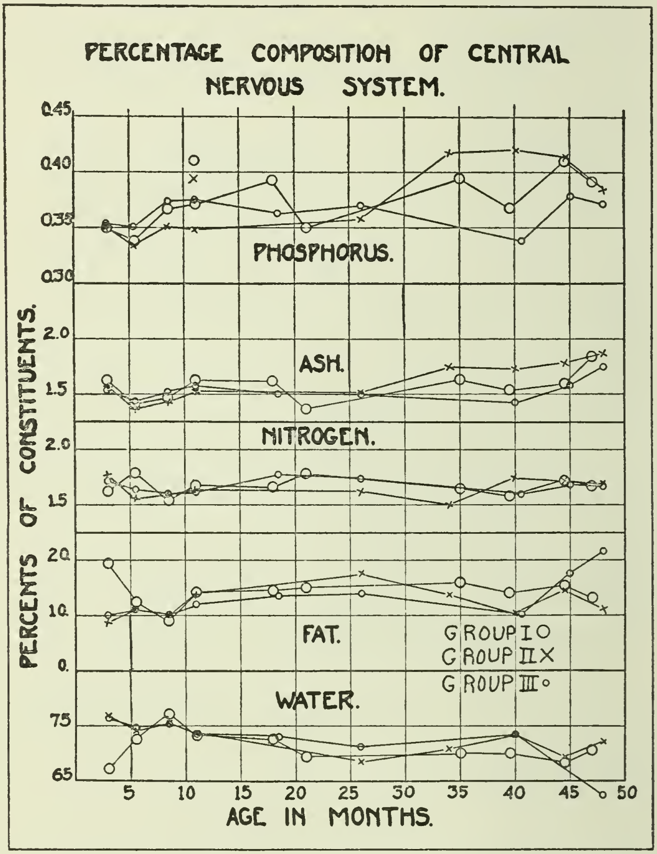

Fig. 2.—Composition of the central nervous system of beef animals.

but being independent of the plane of nutrition. The phosphorus content is 0.34 to 0.43 percent, increasing with age but being unaffected by the plane of nutrition. Steers 503 to 505 give too high values for their age. This sample is rather typical of the glands of the animal body being higher in ash and phosphorus than any class of tissue but the skeleton.

Digestive and Excretory System.—The composition of the composited digestive and excretory system is shown in figure 3. The external fatty tissue has largely been removed from this system. The water is 66 to 78 percent, the fat 3 to 19 percent, the nitrogen 2 to 2.6 percent, the ash 1.5 to 0.8 percent, and the phosphorus 0.27 to 0.15 percent. The fat content increases with age and plane of nutrition while the water, nitrogen, ash and phosphorus decrease up to the age of 3 years. Thereafter the fat decreases again while the other constituents increase. This may be due to the fact that the offal fat is somewhat more easily and completely removed from the older and fatter animals.

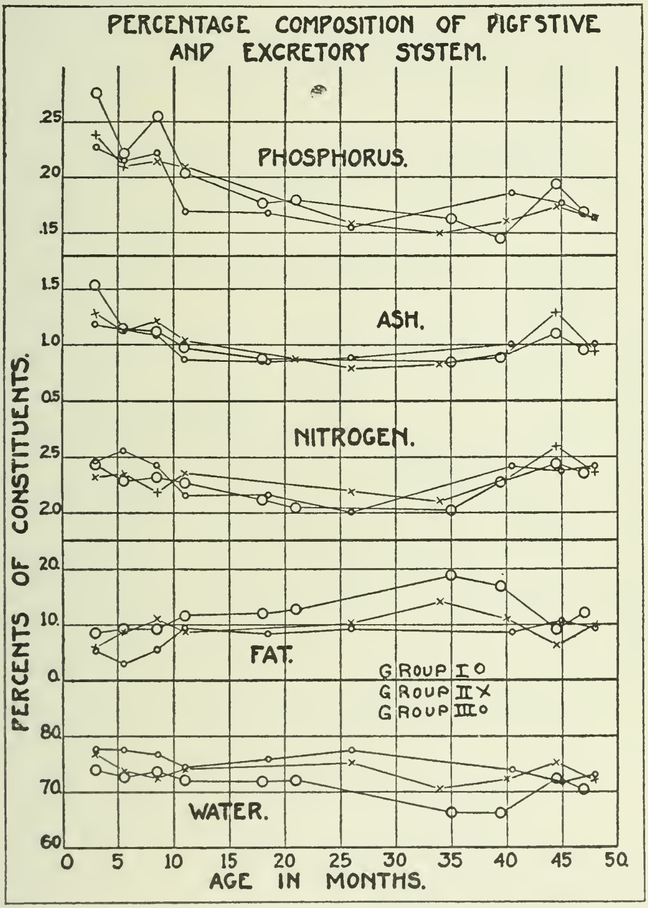

Fig. 3.—Composition of the digestive and excretory system of beef animals.

The Liver.—The above sample is a conglomerate of several classes of tissue in which the glandular predominates. As an example of pure glandular tissue the liver will serve. Figure 4 shows the composition. With few exceptions the composition of the liver from 3 months to 4 years is strikingly constant. The water content is about 67 percent, the ether soluble matter 2 to 3

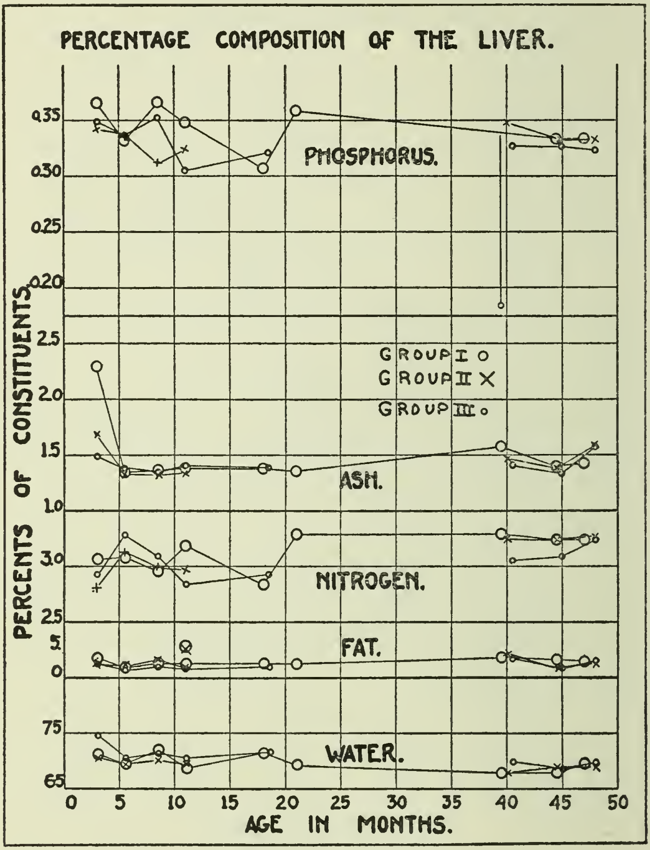

Fig. 4.—Composition of the liver of the beef animals.

percent, the nitrogen 2.8 to 3.3 percent, the ash 1.35 to 1.60 percent and the phosphorus 0.30 to 0.35 percent. The plane of nutrition does not seem to affect the composition, and age has but little effect. There is a slight decrease in water and increase in fat, nitrogen and ash with increasing age. The ash content of the 3-months-old Group I animal and the phosphorus content of Steer 527 are considered to be atypical and are probably due to errors. Again

as with the brain and spinal cord the ash and phosphorus content is quite high while the nitrogen content is about that of muscle tissue.

The Spleen.—In contrast to the above glands the spleen (figure 5) has a rather constant composition and low fat content. The fat runs from 1.5 to 5 percent and is slightly greater in the Group I animals. It increases slightly with age. The water content is 75 to 78 percent. The nitrogen content is from 2.9 to 3.3 percent in the young animals and from 2.75 to 3.0 percent in the old animals.

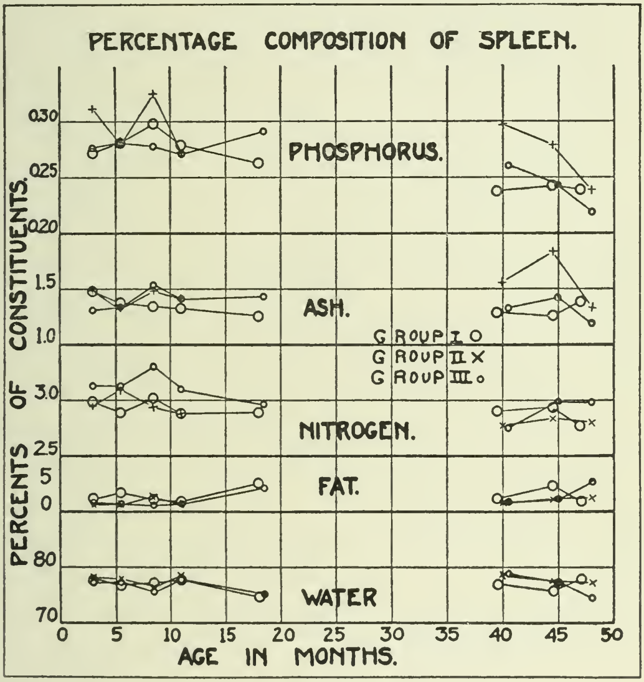

Fig. 5.—Composition of the spleen of beef animals.

With the exception of two of the Group II animals the ash content is constant at 1.3 to 1.5 percent. The phosphorus varies from 0.260 to 0.325 percent in the young cattle and from 0.300 to 0.220 percent in the old cattle. It seems to decrease somewhat with age. On the whole the plane of nutrition has practically no effect on the composition of the spleen and there is but a slight change with age.

The Heart and Neck Sweetbreads.—Not all of the other glands of the animals were analyzed as separate samples. In a number of cases the sweetbreads, spleen, pancreas and kidneys were analyzed as separate samples. No figure is shown for these glands but

a study of the tables in the appendix shows that the heart and neck sweetbreads have from about 2 to over 60 percent fat and from 80 to 30 percent water. The nitrogen content runs between 1 and 3 percent following the water content. The ash and phosphorus are 1.7 and 0.34 percent respectively in the samples low in fat and about one-third those amounts in the samples high in fat. The

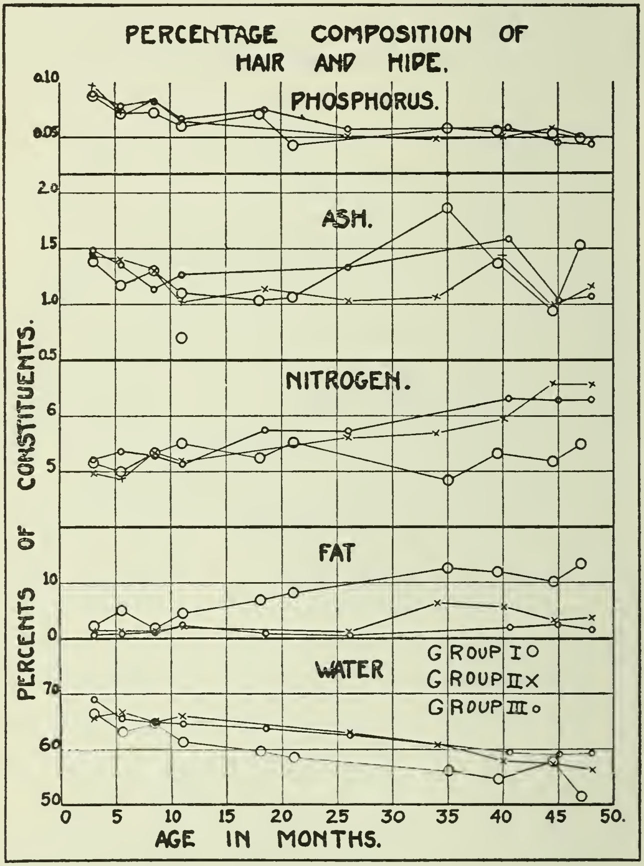

Fig. 6.—Composition of the hair and hide of beef animals.

fat content increases in the older fatter animals while the other constituents decrease. The pancreas is much like the heart and neck sweetbreads in composition. Both of these glands—the thymus and the pancreas—become so intermingled with fat in the older fatter animals that a good separation is impossible.

The Kidneys.—The composition of the kidneys is rather constant. The water content is 74 to 78 percent. The fat content runs

from 2 to 12 percent, but on account of the lack of uniformity in removing the kidney fat from the pelvis of the kidney this variation is not considered significant. The nitrogen varies from 2.08 to 2.7 percent, the ash from 1.00 to 1.35 percent, and the phosphorus from 0.19 to 0.25 percent.

The Hair and Hide.—The hair and hide (figure 6) is a rather dry tissue having from 50 to 70 percent water, 1 to 13 percent fat, 4.8 to 6.6 percent nitrogen, 1 to 1.5 percent ash, and 0.10 to 0.05 percent phosphorus. The nitrogen content is higher than in any other tissue excepting hoofs, dewclaws, and horn exclusive of the bony core. The fat increases with age and plane of nutrition while the water content does just the reverse. The nitrogen percentage increases with age and is in inverse order to the plane of nutrition. The ash content seems to be rather independent of age and nutrition. It was difficult at times to insure perfectly clean hides at slaughter and some of the variations in ash content may be due to dirt on the animal. The phosphorus content decreases with age and seems to vary but little between the different planes.

The Offal Fat.—The composition of the offal fat is shown in figure 7. A large range in composition is shown. This tissue has from 60 to 6 percent of water, 30 to 93 percent fat, 1.7 to 0.2 percent nitrogen, 0.7 to 0.1 percent ash, and phosphorus 0.12 to 0.01 percent. The fat increases with age and plane of nutrition, while all the other constituents decrease. The greatest changes are between the ages of 3 and 11 months.

The Skeleton.—The composition of the skeleton, or bone, is shown in figure 8. The water content is from 30 to 57 percent, the fat from 8 to 23 percent, the nitrogen from 3 to 3.5 percent, the ash from 15 to 27 percent, and the phosphorus from 2.5 to 5 percent. The fat increases with age and is generally higher in the well fed animals although the difference is not great. The water content is just the reverse. The nitrogen content averages slightly higher in the older animals than in the younger animals while the plane of nutrition seems to have no effect. The ash and phosphorus content of the older animals is about double that of the 3-months-old animals. This ossification is on the whole rather gradual. The plane of nutrition is here without effect.

It has been shown in earlier work of this Experiment Station (Research Bulletin 28) that it is a difficult matter to alter the composition of the bone by the plane of nutrition. The present study shows that aside from the small difference in fat and water content

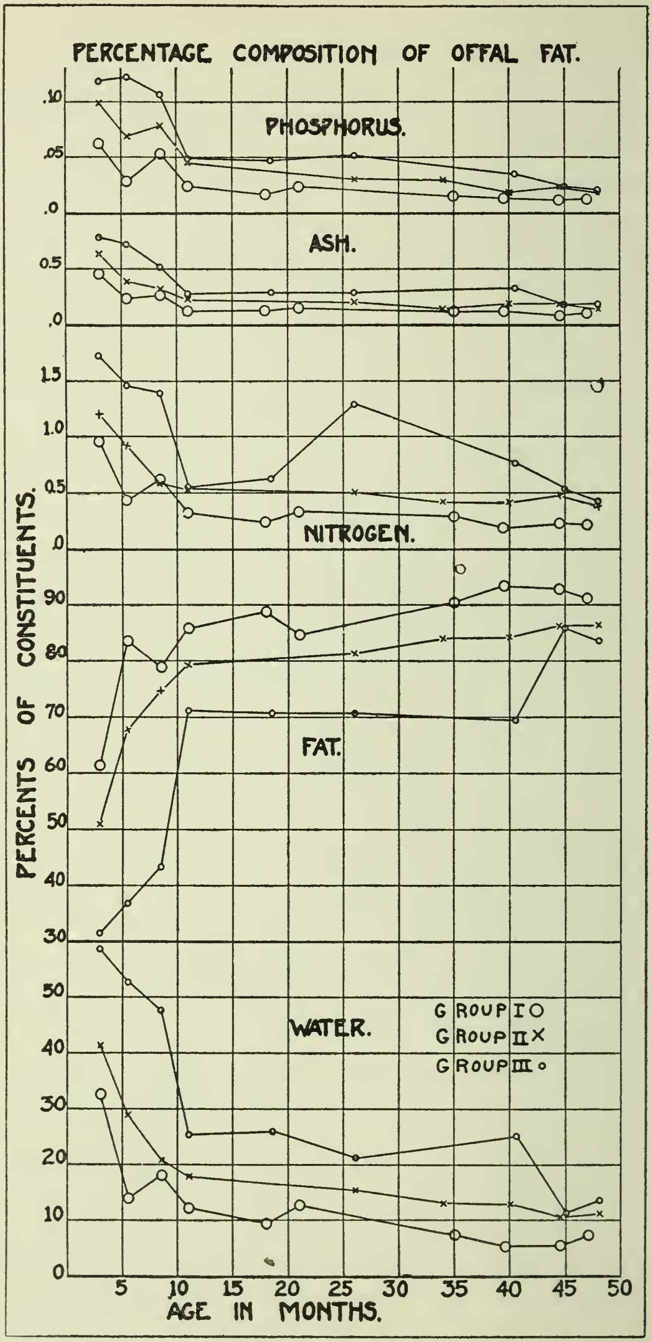

Fig. 7.—Composition of the offal fat of beef animals.

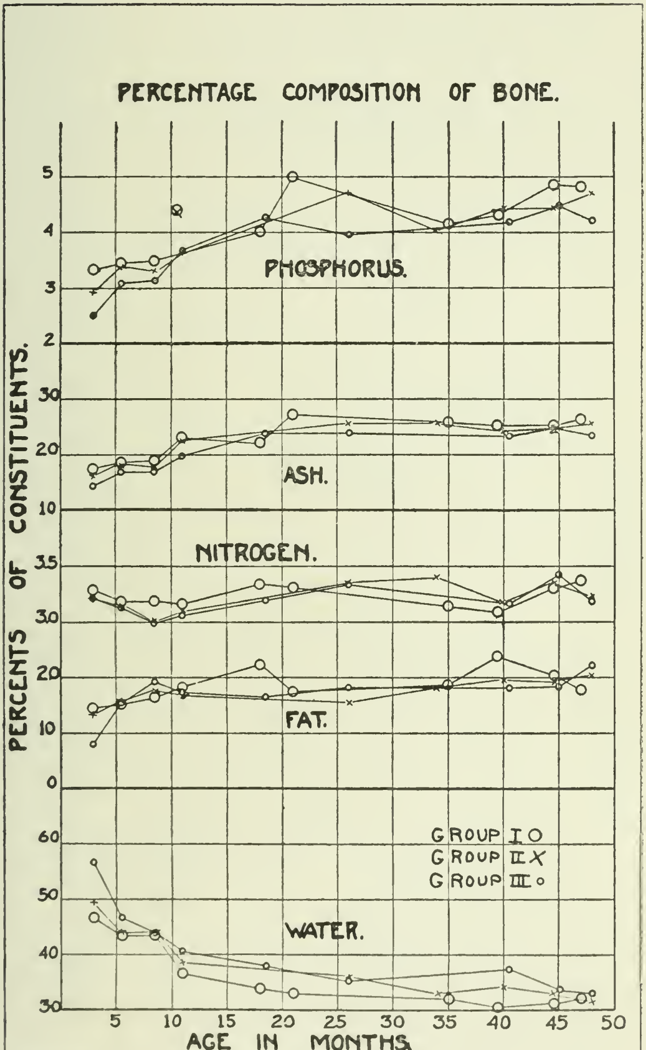

Fig. 8.—Composition of the skeleton of beef animals.

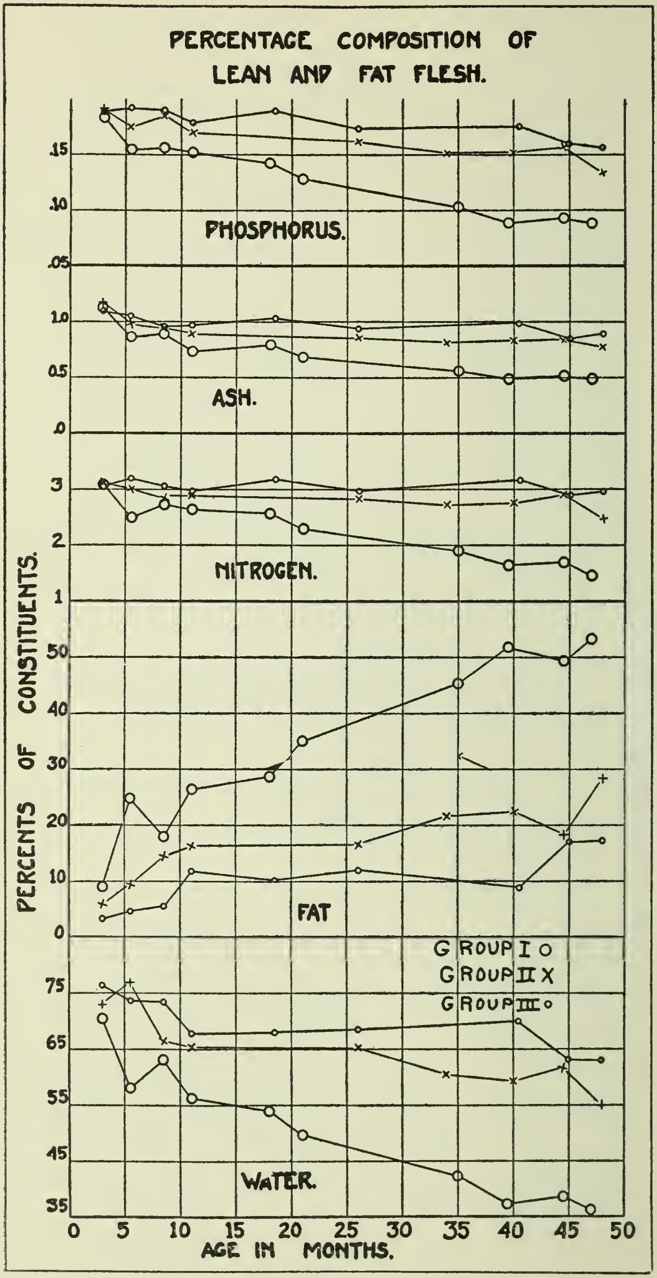

Fig. 9.—Composition of the lean and fat flesh of beef animals.

the bones are not affected in composition by the three planes of nutrition imposed.

The Lean and Fat Flesh.—The composition of the lean and fat flesh is shown in figure 9. This sample is a composite of all the skeletal musculature and the fatty tissue associated with it. The offal and thoracic fat is not included. The figure shows, mainly, the effect of increasing fatness on the composition. The fat increases with fatness of the animal, i. e., with increasing age and plane of nutrition, while all other constituents decrease. The nitrogen content of the Group II and Group III animals, however, is practically constant at about 3 percent. The water runs from 77 to 36 percent, the fat from 3 to 53 percent, the nitrogen from 3.2 to 1.5 percent, the ash from 1.15 to 0.50 percent, and the phosphorus from 0.190 to 0.090 percent.

The Total Animal.—The composition of the total animal analyzed is shown in figure 10. The figures are for the total animal less the fill and the loss on cooling and cutting. This basis is designated as the analytical animal in Tables 72 and 73. The average composition of 13 beef calves at birth* is included in the figure. The water content decreases from 73 percent at birth to 39 percent in the old fat steer. The higher the plane of nutrition and the older the animal the lower is the percent of water. The fat increases from about 4 percent at birth to about 45 percent. The increase follows age and plane of nutrition. The nitrogen shows first an increase from 2.9 percent at birth to 3.3 percent at 3 months. It remains practically constant thereafter for Groups II and III but decreases in Group I to 2 percent at 4 years. The ash content for Groups II and III increases from 4.5 percent at birth to over 5 percent at 4 years. The high value for the Group III animal at 40 months is probably an error or an abnormality. For the Group I cattle the ash increases to about 5 percent at 3 months, falls to 4 percent at 5½ months and remains there in spite of fattening until after 3 years when it drops to nearly 3 percent. It should be noted that the Group III 3-months-old calf was so greatly retarded in development by the low plane of nutrition that its ash and phosphorus content is actually lower than that of the calves at birth. In general the phosphorus content of the entire animal follows the ash. The values for Steer 505, Group I, and Steer 503, Group II, are so much higher than those of the other animals of their groups

*Research Bulletin 38, Agr. Expt. Station, University of Missouri.

that they are not averaged on the curve but are shown separately. The phosphorus content increases in percentage for Groups II and III but decreases for Group I.

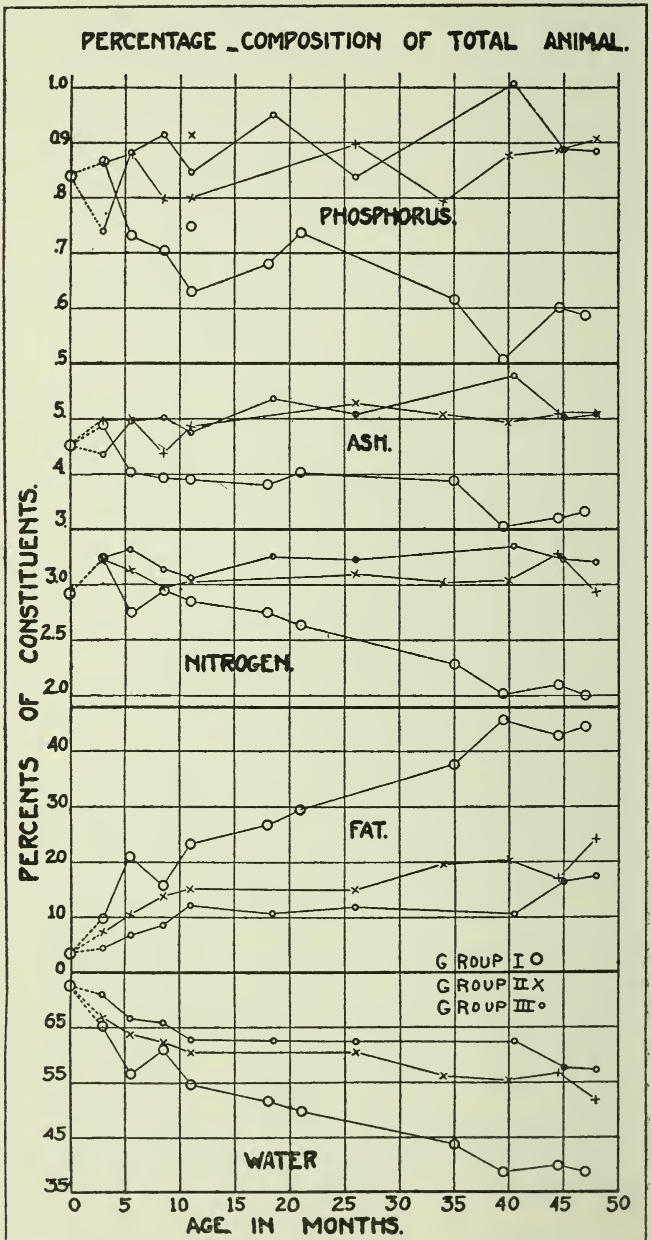

Fig. 10.—Composition of the total animal (empty) of beef animals.

THE COMPOSITION ON A PROTOPLASMIC BASIS

A brief summary of the composition of various parts and samples of the beef steer given above shows that those parts or organs that become depots of deposit for fat, exhibit an increasing percentage of fat with increasing age and plane of nutrition; while most, if not all, other constituents decrease. Certain organs remain fairly constant in composition. It is the belief of the senior author that the composition of animal tissue should be studied also on the fat-free, or protoplasmic, basis. Its usefulness has already been demonstrated by Moulton* and Greene†. In the animal body lipoid matter can be divided largely into two classes: (1) stored and inactive lipins, largely glycerol esters of the higher fatty acids; and, (2) those lipins that are essential to the protoplasmic structure and that take part in the physiological activities of the tissue, such as lecithins and cholesterol. The former is largely if not entirely inert stored matter and should not be considered as part of the protoplasmic tissue. Unfortunately the usual method of extraction by ether removes both classes together; but, since in the fatty tissue and even in the entire body of fat animals the former very greatly predominates, the ether extract can safely be called stored fat.

For the above reasons the composition will now be considered on the fat-free basis. Tables 72 and 73 show the composition of the entire animal on the analytical basis, the empty weight basis, and the fat-free basis. The first basis has been defined just above. The second assumes that the loss on cooling and cutting is water, which it must largely be. This weight is added to the water content and the composition recalculated. The result is a slightly larger water percentage and slightly smaller percentages of the other constituents. The third basis assumes that all ether soluble fat had been removed.

Thirteen calves at birth and three embryos reported in Research Bulletin 38 of this Station are included in the tables. In order to complete the picture of the development of the composition of mammalian tissue a search has been made for analyses of other mammalian embryos. On account of the length of the gestation period and relative size of the animal it is thought that rabbits and other mammals cannot serve our purpose. The composition of some 21 human embryos reported by Fehling‡ in 1877 and recalcu-

*J. Biol. Chem. XLIII, 67.
†J. Biol. Chem. XXXIX, 435.
‡Archiv. f. Gynaekologie XI, 523.

lated by the senior author to the fat-free basis have been added to the results obtained from the bovine.

Figure 11 shows the water content of the animals on the fat-free basis from the beginning of gestation to maturity. The gestation periods for man and the ox are practically the same. Man is less mature at birth, however, and this should be borne in mind in considering the composition of the full term human infant. The water content of the fat-free human embryo at the beginning of the sixth week of gestation, or at an intra-uterine age of 35 days, is 97.5 percent. It decreases rapidly and uniformly to about 86 percent at 6 months. It is seen that the ox embryo at this age has practically the same composition as the human. At birth the ox has 76.5 percent water. The human infant being less mature has 81.5 percent. At the age of 3 to 5 months there is a marked change in the rate of decrease of the water in the ox. It is about 72 percent at 5 months and 70 percent at 4 years. The plane of nutrition has practically no effect on the composition of the ox, on the protoplasmic basis.

The percentage of nitrogen is shown in figure 11. At about 35 days (intrauterine) it is 0.4 percent. It increases rapidly and uniformly to about 3.0 percent at birth and at 5 months is 3.5 percent. Maturity is reached at about 11 months when the percentage is 3.6. This continues to be the value excepting for a few of the old thin animals which exceed it by about 0.2 percent.

The ash content at 35 days is practically nothing. It increases rapidly and uniformly to 4.3 percent at birth. At 5 months it is 5 percent and thereafter increases slowly to about 5.7 percent at 4 years. There is more variation in the ash content than in the water or nitrogen content. It is higher in the low plane animals than in the high plane animals. This is probably due to a small proportion of bone in the Group I cattle.

The phosphorus content of the human embryos was not given. Therefore the figure shows the results for the ox only. The phosphorus content on the protoplasmic basis is about 0.3 percent at 185 days intrauterine. It increases rapidly to about 0.74 percent at birth. By 11 months the value is about 0.90 percent and thereafter it increases very slowly to 1 percent at 4 years.

These figures show, then, that the evolution of the tissue of such mammals as the ox is rapid from conception to shortly after birth—about 5 to 11 months in the ox. Thereafter the composition on the fat-free, or protoplasmic, basis is practically constant

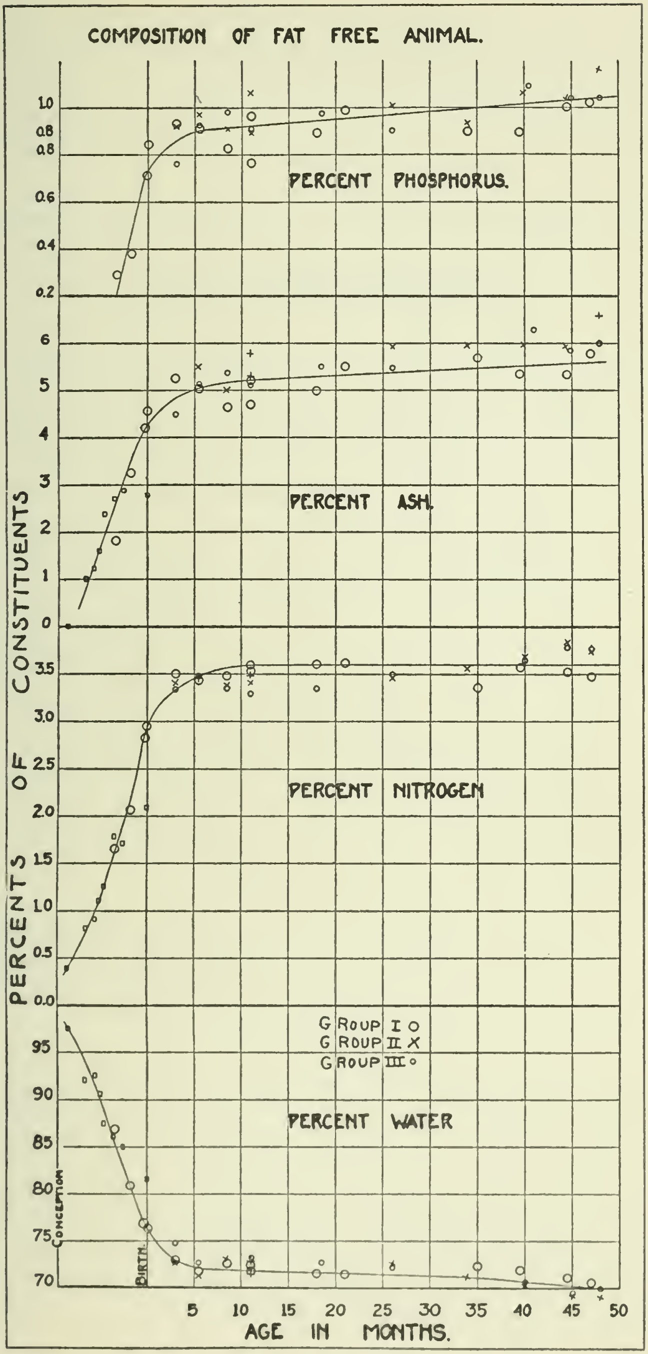

Fig. 11.—Composition of the fat-free beef animal.

there being but slight changes to full maturity. Such relations as these are entirely destroyed by the presence of stored fat in the animal body and would be left undiscovered if the fresh, fat-containing basis were used.

THE COMPOSITION OF OX MUSCLE ON THE PROTOPLASMIC BASIC

The above results show the advisability of studying the composition of such tissues as striated muscle on the fat-free basis. Unfortunately only the composite embryo was studied by us. However, Buglia and Costantino* have recently reported some analyses of ox embryo muscle. Three samples of embryo muscle at 75, 120 and 135 days were analyzed for water, fat and nitrogen. These results are included with all samples of lean muscle reported in this bulletin and are shown in Tables 74, 75, and 76.

Figure 12 shows the percentage of water in ox muscle from miduterine life to maturity. At mid-term the tissue is 87.5 percent water. At birth it is 80 percent and at 5½ months it is 77 percent. It remains practically constant then at 76.5 percent with no apparent effect on the plane of nutrition. Perhaps more rigidly controlled conditions in sampling and analyzing might have resulted in less variation than is shown. The water content of the muscle is 5 to 6 percent higher than in the total animal.

The nitrogen content is shown in figure 12. At miduterine age it is 1.4 percent, at birth 2.9 percent, and at 11 months 3.5 percent which is the value maintained to the end. This value is slightly less than that for the total animal.

The percentage of ash exhibits some striking changes. There are no figures preceding birth. At birth the ash in the fat-free muscle is 1.05 percent. At 3 months of age it has risen to 1.28 percent and falls to 1.11 percent at 6 months. From then on it decreases slowly and gradually to 1.06 percent at 4 years. The peak at 3 months may need verification, but it is a fact that only one other animal, the Group II steer at 40 months, exhibits anywhere near as high a figure.

*Z. Physiol. Chemie 81 (1921), 143 and 155.

The phosphorus percentage in the fat-free muscle exhibits some rather similar changes. At birth the tissue shows about 0.172 percent and at 3 months 0.218 percent. The value thereafter falls fairly rapidly and uniformly to about 0.200 percent at 4 years. The figure confirms in general the relations shown by the ash percentages.

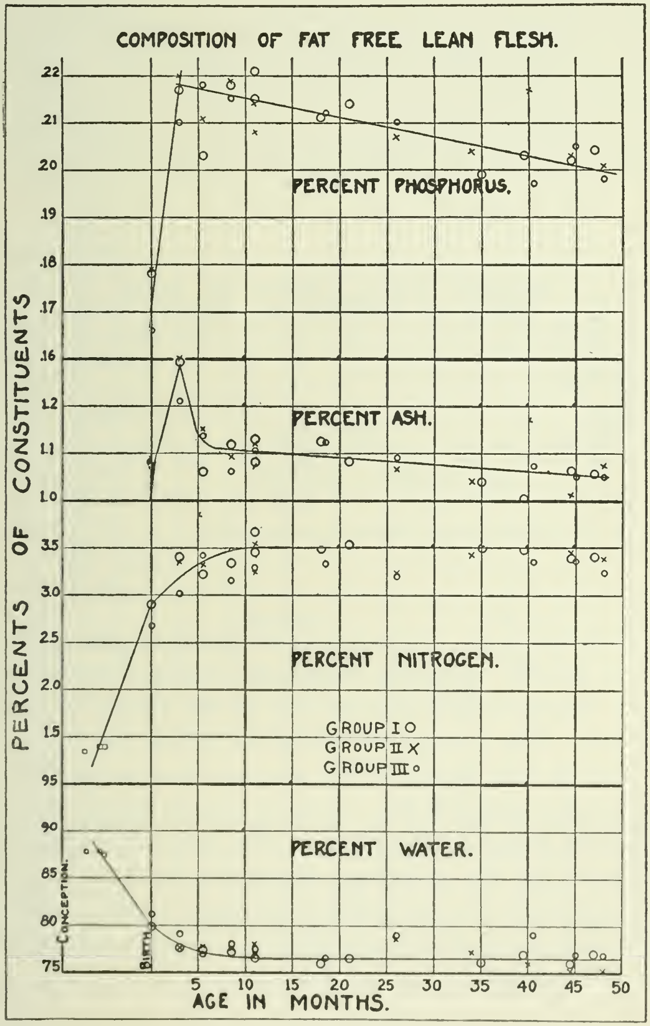

Fig. 12.—Composition of the fat-free lean flesh of beef animals.

AMOUNT AND COMPOSITION OF GAIN

Composition of Gain From Start to Slaughter.—The composition of the animal at slaughter is given above. In order to calculate the composition of the gains made by each steer from the time it was put in the experiment until slaughter it is necessary to know the weight and composition at the start. The weight for each animal at the beginning of the experiment is shown in the Appendix of Research Bulletin 43 of this series. Since the analysis is based upon empty weight in Tables 72 and 73 it is necessary to estimate the empty weight of each calf at the start. To facilitate this the percentage of empty weight is plotted against the live weight in

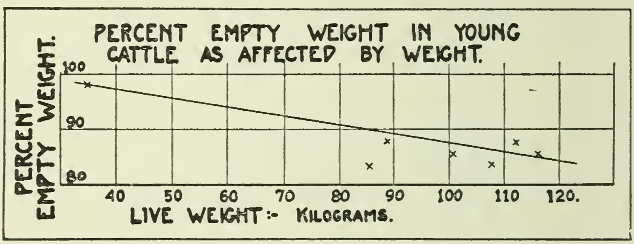

Fig. 13.—Percent empty weight in young cattle.

kilograms in figure 13. Only calves of 100 kilograms empty weight or less are shown. The line shows the relation between the percentage of empty weight and the size of the animal for a normally fed beef calf. The Group III calves lie below the line. The live weight used in this figure is the average live weight for the last five days of the animal's life. This is usually larger than the live weight before slaughter because at that time the cattle had been without water for the morning. From this figure it is possible to estimate accurately the probable percentage of live weight in each calf at the beginning of the experiment. Table 77 gives the empty weights at the start.

In figure 14 are presented the relations between the empty weight of young calves and the composition of the calf. The composition at 35 kilograms is the average of 13 beef calves at birth. The lines show a fairly uniform relation between empty weight and composition. Using the empty weight of the calves shown in Table 77 the composition of each calf at the start can be accurately estimated.

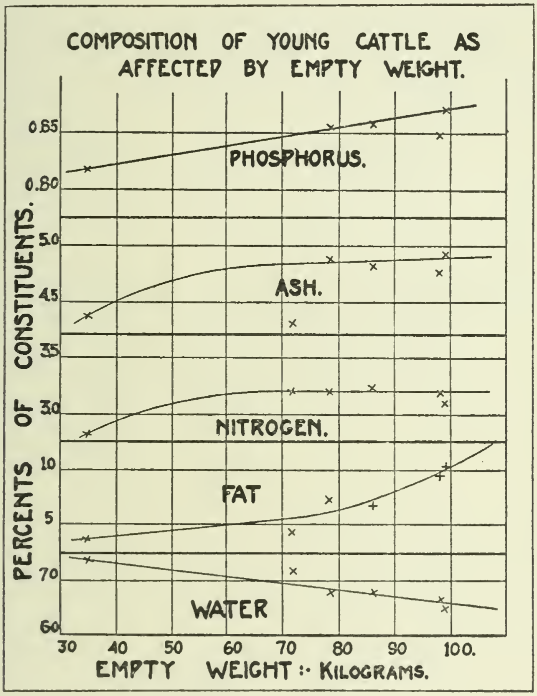

Fig. 14.—Composition of young cattle.

Table 78 shows the weights and percentage of each constituent for each animal at the start and at slaughter and the composition of the gain made. The animals are not in all cases ideal checks on each other consequently the composition of the gain does not vary uniformly. Figure 15 shows the composition of the gains made by each group from the start to slaughter.

The first gains of the thinnest cattle are 80 percent water the next gain is but 62 percent water. The water increases slightly to 18.5 months and then decreases slowly. The Group II cattle

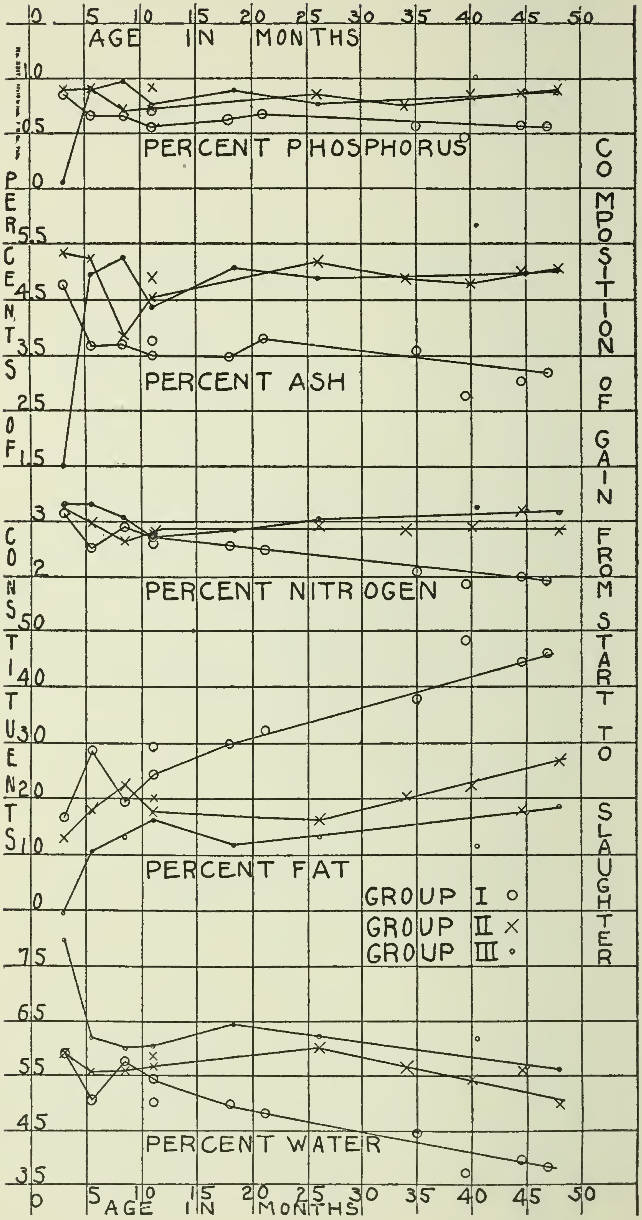

Fig. 15.—Composition of total gains of beef cattle.

show much the same sort of change but in a less marked degree. For the Group I cattle the gains at first are 50 to 60 percent water and only 38 percent at 4 years.

In contrast to this the gains made by all cattle become higher in percentage of fat as the age advances. The Group III calf at 3 months actually shows a loss of fat. The next gain was 10 percent fat and at 4 years the gain contained 18 percent fat. The Group II cattle show increasing percentages of fat up to 11 months when growth becomes so rapid that the animal becomes relatively thinner and the gains contain relatively less fat. At 4 years the gain contains 27 percent of fat. The Group I cattle show this thinning down at 8½ months. Thereafter the gains increase rapidly in fat, containing at 4 years as much as 46 percent of fat.

The gains of the Group I cattle decrease in percentages of nitrogen excepting during the period of rapid growth at 8½ and 11 months when there is an increase. At the start the gain contains about 3.15 percent nitrogen and at the end only 1.9 percent. The Group II cattle show a decrease in percentage of nitrogen in the gain at first followed by a slight increase. Then the value becomes constant at 2.9 percent. The Group III cattle show much the same thing excepting that the value continues to increase up to 40 months when it is almost as great a part of the gain as it was at 3 to 5 months.

As for the ash gained the Group III cattle show a very low percentage at 3 months with a very rapid recovery at 5½ months. Thereafter the value is fairly constant at 5 percent. The Group I and Group II cattle at first show the opposite tendency, the gains containing a relatively smaller percentage of ash. The Group II cattle then show a gradual increase to 2 years, after which the value is rather constant at about 5 percent. The Group I cattle continue to show a decrease in the percentage of ash with some rather large individual variations. The phosphorus content of the gains made in general follows the ash.

It has perhaps been noticed that the lines miss a few of the points by a large margin. The following reasons will account for this. Steers 505 and 503, representing Groups I and II respectively, were among the first animals killed and analyzed. The other animals at this age—11 months—differed in weight or composition from these first two. There must be some difference in age or treatment to account for some of the large differences. Steers 505

and 503 are not considered to be quite typical. Again Steer 527, the Group I steer at 40 months, was too fat for its age and Steers 502 and 524 were too thin for their ages and groups. The former was the Group II 45-months animal and the latter the Group III 40-months animal.

Figure 15 (as does also figure 10 which gives the composition of the total animal) raises the question of the regularity of the change

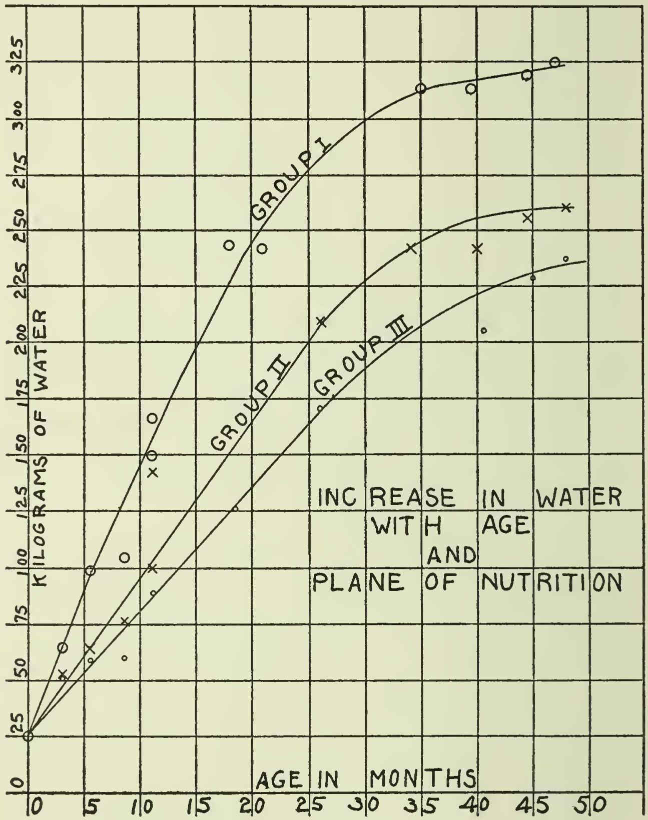

Fig. 16.—Quantity of water in beef cattle.

in composition of the cattle and of the rate of deposition of each constituent. To throw more light on these questions there is presented in figure 16 the weight of water found in each animal slaughtered. At birth it is about 25 kilograms. In the Group I cattle this increases rapidly and uniformly to 250 kilograms at 21 months. The rate of increase then declines until at about 35 months the steer has almost as much water as at 47 months. The curves

for the other groups are rather similar excepting that for Group II the break in the curve is at 26 months and flattening occurs at 40 months. For Group III the rate of increase has been still less, the break occurs at about 27 months and the flattening is at the end if present at all.

In marked contrast to these curves are those for the fat shown

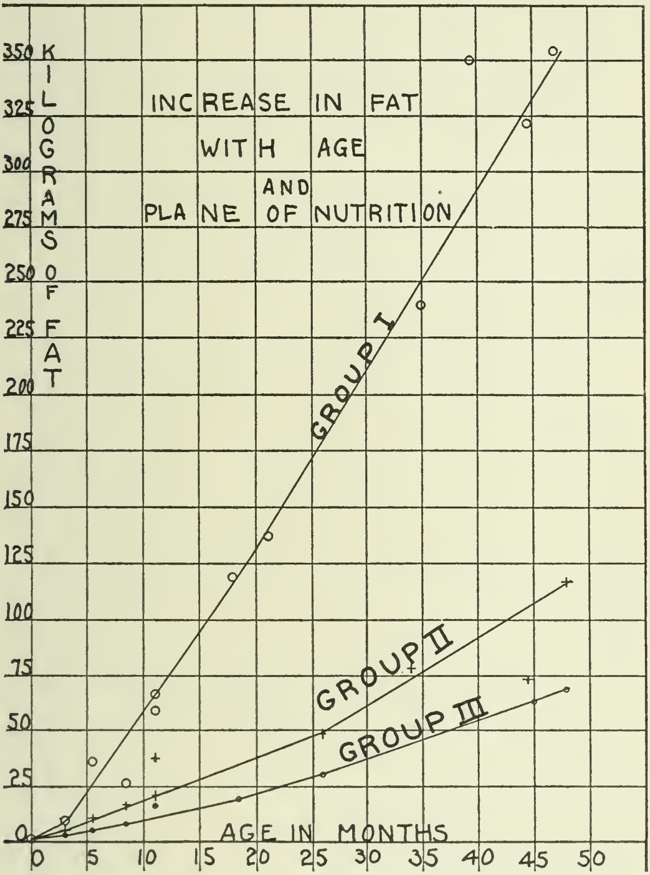

Fig. 17.—Quantity of fat in beef cattle.

in figure 17. After the third month the Group I cattle deposited fat at a rapid and very uniform rate averaging 7.86 kilograms per month. The curve is very slightly convex to the (abscissae) horizontal axis. For the other groups the rate of increase in weight of fat is very much smaller and the curves are more convex to the horizontal, i. e., the rate of deposition increases more with age.

Figure 18 shows the weights of nitrogen (or protein), ash, and phosphorus for each animal slaughtered. In general the curves resemble the curves for water more than they do the curves for fat. The Group I cattle show a decided break in the building up of protein at 20 months and a further break at 40 months. The curves for the other groups are very similar. Both the ash and the phosphorus, on the other hand, fail to show the flattening of the curve after three years.

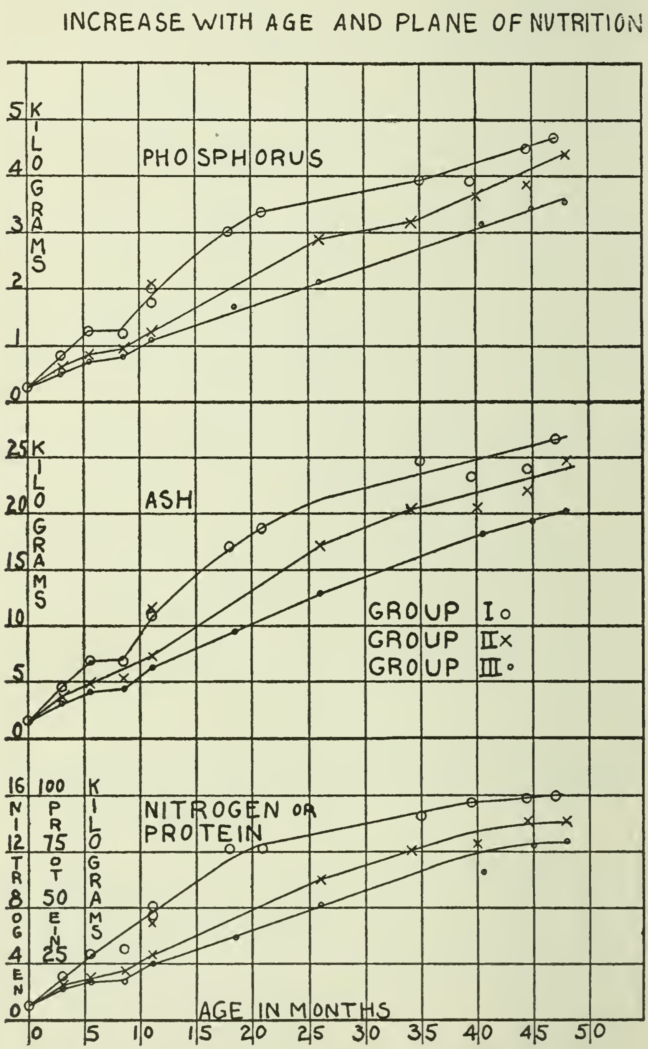

Fig. 18.—Quantity of nitrogen (protein), ash and phosphorus in beef cattle.

COMPOSITION OF GAIN BETWEEN EACH AGE

In order to calculate the composition of the gains made between the succeeding ages it is necessary to assume that each steer slaughtered had at the age at which the preceding steer was slaughtered the composition of that steer both in percentage composition and in percentage of empty weight. Table 79 gives the percentage of empty weight referred to the live weight at the end of the feeding period (a five-day average). This is more representative of conditions in the pen than when the live weight just preceding slaughter is used.

For the live weight at the age at which the preceding animal was slaughtered the live weight at the beginning of that period which came nearest to giving the correct age was used. This facilitates the calculations and is as correct as any of the assumptions. The composition of the gains made between each succeeding age for each group is given in Table 80.

A study of the table shows that on the whole each animal at the time of slaughter contained more of each constituent than it did at the time the preceding animal was slaughtered. This is true with all but one animal in each group in the latter months. In these cases the three steers—527 in Group I, 502 in Group II, and 524 in Group III—were not of normal condition for the group, the first being too fat and the latter two too thin for the age and group. These statements are borne out by data presented above on the composition of the steers and by the proportion of lean, fat and bone shown by these animals in Research Bulletin 54. These animals must be omitted entirely from a study of the composition of the gains made between successive ages or else the composition of normal animals of the respective ages and groups must be used in place of the composition shown by those abnormal steers.

From figure 10 the percentage of fat a steer should have on these three planes of nutrition can be read off for any given age. By its use it is estimated that Steer 527 should have had 38.5 percent of fat, Steer 502 should had had 20.3 percent of fat, and Steer 524 should have had 15 percent of fat. From figure 11 the normal composition of the fat-free animal is readily determined. Calculating these values to the fat content just given it is found that these animals should have had the following composition.

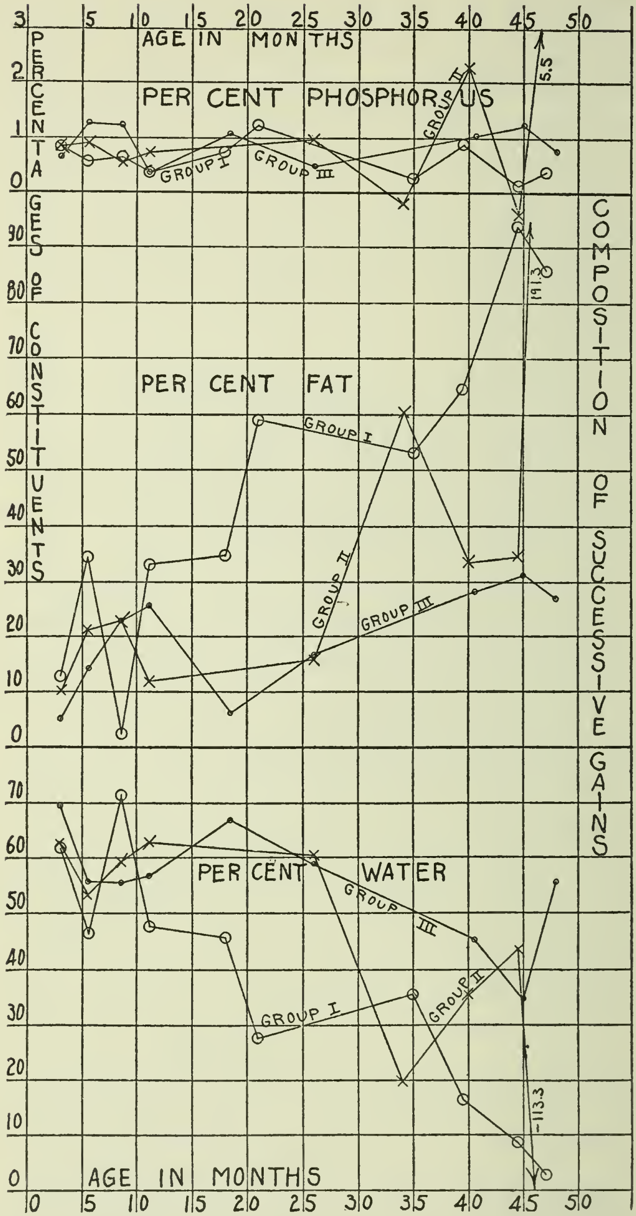

Fig. 19.—Composition of successive gains of beef cattle—water, fat and phosphorus.

Estimated Percentage Composition.

Steer	Water	Fat	Nitrogen	Ash	Phosphorus
527	43.48	38.5	2.21	3.38	0.615
502	56.03	20.3	2.87	4.46	0.797
524	60.00	15.0	3.06	4.70	0.850

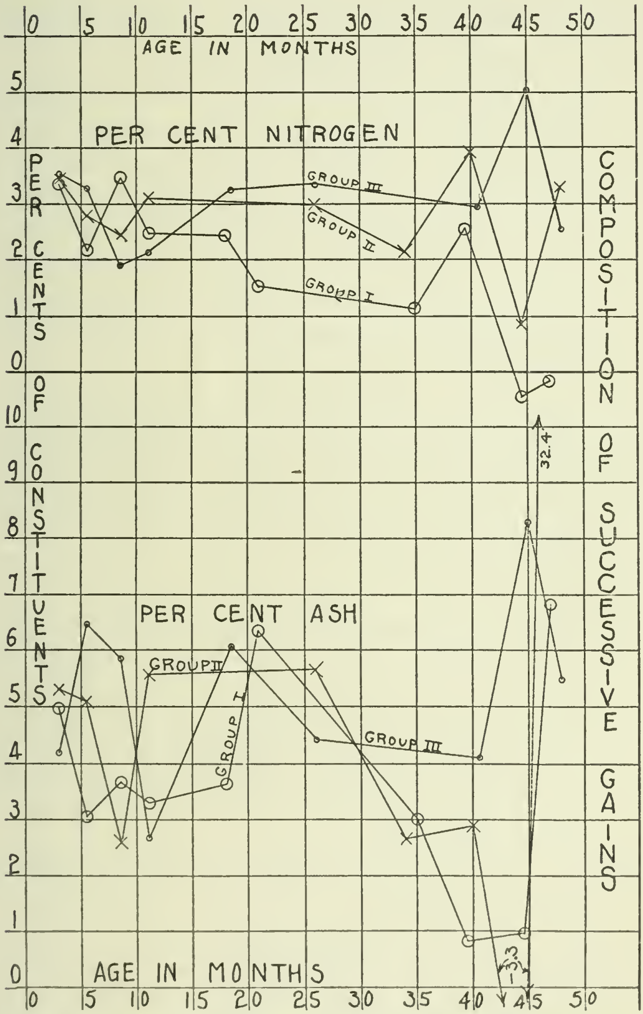

Fig. 20.—Composition of successive gains of beef cattle—ash and nitrogen.

From these values the composition of the gains as shown in the latter part of the table are calculated. These corrected results are shown graphically in figures 19 and 20.

Water.—The water content of the gains made by the Group I steers decreased as the animals got older and fatter. The 8½-months-old steer had been growing rather rapidly and these gains were largely protoplasmic tissue as shown by the high water and nitrogen content of the gain. From gains containing 60 to 70 percent of water the change becomes rapid to gains containing 30 to 40 percent of water. After 35 months the water content drops until at 47 months it is only a little over 2 percent.

The Group II steers after an initial decrease in percentage of water in the gains show a rise to 11 months. This would indicate that their development was about 3 months behind the Group I cattle. At 34 months the steers become rather fat having only 20 percent of water in the gain made during the past 8 months. The next gains contain more water. The 48-months-old steer of this Group was too fat (and too well supplied with bone at the same time). Consequently his last gain appears to contain —113 percent of water. This is, of course, impossible.

For the Group III steers there is the initial fall in percentage of water in the gains followed by a rise with the maximum in this case deferred to 18 months. The water content of the successive gains then falls to about 34 percent at 45 months and shows a rise to about 55 percent at 4 years.

Fat.—In general the fat content of the successive gains is inversely to the water content. The first gains contain about 10 percent of fat. This increases, after an initial fall with minima occurring where the water showed maxima, to 90 percent for Group I and only 30 percent for Group III. The Group II cattle lie between these, but on account of the wide abnormality of the 4-year-old Group II steer the last gain appears to contain 191 percent of fat. This is of course impossible.

Nitrogen.—The nitrogen content of the gains is shown in figure 20. In general it follows the water and is inversely to the percentage of fat. The Group I cattle show gains containing over 3 percent of nitrogen at first. The percentage of nitrogen decreases until at about 4 years the gains contain no nitrogen (—0.45 and —0.15 percent). The Group II and Group III cattle show gains containing over 3 percent nitrogen at first. This percentage falls to less than 2 percent for Group III and about 2.5 percent for Group II. There is then an increase to over 3 percent again. Towards the end there are some rather sudden changes which can only be

accounted for by individual differences in the steers. At the end the values are not far from 3 percent in either case.

Ash.—The ash content of the gains shows some rather striking changes. For the Group I cattle the percentage drops from 5 to 3 or 3.6 percent. But the 21-months-old steer shows a gain containing over 6 percent ash. The value then falls to 3 percent and 1 percent at 44½ months. However at 47 months the gains contain nearly 7 percent of ash. These changes are partly due to different proportions of bone in the cattle. The Group II cattle follow Group I in general. At 8½ months the gain contains but 2.6 percent ash. It then shows a rise to nearly 6 percent falling rapidly after 26 months. The last two steers show abnormal values, the 45-months-old steer showing the gain of the last 5 months to contain —3.3 percent of ash and the 4-year-old steer showing for the last 3 months a gain containing 32.37 percent of ash. These last two values are, of course, impossible and bear witness to the abnormality of the 4-year-old Group II steer as well as to the different proportions of bone in the last two animals.

The Group III animals indicate that the early growth of the calves has been so retarded that the bone is insufficiently developed. The gains made immediately after 3 months contain 6 percent of ash and show that the animals are recovering in this respect. There is a big drop in the ash content of the gain made just preceding 11 months. The following gain is higher in ash and there then follows a decrease. Towards the end there is another increase in the percentage of ash in the gains.

Phosphorus.—The percentage of phosphorus in the successive gains is shown at the top of figure 19. On the whole the values appear fairly constant. This is partly due to the scale of the figure. The percentages vary much as do the ash percentages. The 4-year-old Group II steer is again abnormal and shows the gain for the last 3 months to contain 5.5 percent of phosphorus.

SUMMARY

Thirty Hereford-Shorthorn beef animals ranging in age from 3 months to 4 years were used in this experiment representing three different planes of nutrition. An average of 35 samples per animal or a total of 1061 samples were analyzed for water, fat, nitrogen, ash, and phosphorus.

The chief effect of age and plane of nutrition on the composi-

tion of parts and total animal is through a change in the fat content, which increases in most cases with age and plane of nutrition. The skeleton shows greatly increasing ash and phosphorus content with advancing age.

The total empty animal shows an increasing fat content and decreasing percentage of other constituents with age and plane of nutrition excepting where the fattening is slight and a small increase in nitrogen, ash and phosphorus becomes apparent. When calculated to the fat-free basis, however, the total animal shows very striking changes in composition depending on age alone. The water content decreases rapidly from conception to about the age of 6 months and then becomes constant. The other constituents show a rapid increase to a maximum. For nitrogen and phosphorus the maximum is attained at about 11 months. The ash does not attain a maximum and constant value but from 5 months to 4 years increases slowly.

The composition of the composite ox muscle on the fat-free or protoplasmic basis shows somewhat similar results. The minimum for water and the maximum for ash occur at about 6 and 11 months respectively. The ash and phosphorus content show irregularities having a marked maximum at 11 months with a decreasing percentage thereafter.

The amount and composition of the gains from start to slaughter and between each succeeding age have been calculated. The beef steer may contain 4 percent fat at birth and 45 percent at 4 years. For the full fed cattle the gains become richer in fat and poorer in other constituents with advancing age until the last gains are shown to consist of 90 percent fat. With the other groups there is some variation. All groups show a thinning down during the early months and a fattening after the period of rapid growth is over. The thin cattle have a more nearly constant composition after the first few months.

The irregularity of the percentage composition of the gains raises a question as to the uniformity of the treatment. It is shown that the weight of water in the fattening beef steer increases rapidly to 21 months and then slowly to 35 months. With the poorer groups the flattening of the curve occurs at 26 months and 40 months. The deposition of fat was very uniform from 3 months on for the full fed cattle and slightly increasing with age for the poorer cattle.

APPENDIX

Table 1.—Steer 500. Analysis of Samples.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	21,269	79.041	0.192	3.193	0.789	0.022
Circulatory system	1,562	48.451	37.638	1.867	0.541	0.061
Lean heart	1,284	77.544	3.559	2.723	1.107	0.208
Respiratory system	3,747	76.501	2.702	2.840	1.145	0.172
Fat from thoracic cavity	568	17.038	79.391	0.489	0.239	0.024
Brain and spinal cord	832	62.766	21.718	1.667	1.748	0.371
Digestive and excretory system (partial)	19,275	74.635	9.971	2.203	0.834	0.118
Offal fat	12,940	13.501	83.556	0.422	0.184	0.020
Heart and neck sweetbreads	538	53.199	33.943	1.837	1.043	0.224
Liver	4,634	69.786	2.902	3.243	1.579	0.323
Gall	241	91.875	0.219	0.200	1.237	0.027
Spleen	1,054	74.374	5.355	2.977	1.196	0.219
Pancreas	625	59.139	25.091	2.140	1.201	0.256
Kidneys	1,019	77.091	4.806	2.420	1.120	0.207
Tongue, marketable (excl. bones)	1,619	69.404	11.874	2.703	0.914	0.154
Hair and hide	35,938	59.327	1.319	6.280	1.072	0.044
Head and tail, lean and fat	3,784	63.713	15.958	3.155	0.882	0.134
Shin and shank, lean and fat	12,496	70.862	6.591	3.363	0.989	0.164
Flank and plate, lean and fat	36,410	54.788	27.651	2.687	0.866	0.139
Rump, lean and fat	7,058	55.149	27.639	2.527	0.819	0.145
Chuck and neck, lean and fat	58,918	67.594	11.869	3.387	0.912	0.158
Round, lean	39,898	74.031	3.485	3.123	1.011	0.191
Round, fat	4,936	27.767	61.442	1.590	0.377	0.051
Loin, lean	29,692	70.269	7.734	3.113	1.010	0.185
Loin, fat	6,830	16.464	76.508	0.598	0.245	0.038
Rib, lean	13,602	67.137	12.323	3.196	0.929	0.170
Rib, fat	1,804	20.368	71.084	1.293	0.370	0.060
Kidney, fat	2,432	7.026	90.275	0.410	0.143	0.018
Skeleton of feet	6,838	39.603	11.528	3.612	24.970	4.529
Skeleton of head	8,953	47.986	13.584	3.487	17.862	3.434
Skeleton of tail	386	39.305	24.024	2.650	15.917	2.786
Skeleton of shin	5,610	26.487	21.585	3.700	29.441	5.211
Skeleton of shank	5,750	31.458	20.187	3.454	25.183	4.429
Skeleton of flank and plate	6,350	41.031	18.008	3.223	18.537	3.200
Skeleton of rump	2,988	24.341	30.609	3.067	25.092	4.430
Skeleton of chuck and neck	14,450	29.775	22.517	3.060	25.926	4.575
Skeleton of round (excl. marrow)	6,438	32.552	27.793	2.589	21.074	3.786
Marrow from skeleton of round	680	9.460	89.251	0.147	0.213	0.031
Skeleton of loin	7,772	25.056	31.376	2.935	24.006	4.277
Skeleton of rib	5,192	27.145	22.308	3.182	27.925	4.952
Hoofs and dewclaws	2,095	50.581	0.837	7.742	2.606	0 117
Teeth	852	21.329	1.162	2.079	61.007	11.516

Table 2.—Steer 501. Analysis of Samples.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	28,710	77.977	0.176	3.290	0.857	0.025
Circulatory system	1,836	41.962	45.889	1.907	0.476	0.049
Lean heart	1,882	77.616	3.738	2.573	0.992	0.198
Respiratory system	3,838	76.577	3.348	2.873	1.041	0.172
Fat from thoracic cavity	2,459	18.834	76.645	0.612	0.237	0.026
Brain and spinal cord	757	70.404	13.274	1.673	1.836	0.392
Digestive and excretory system (partial)	24 235	71.756	12.870	2.143	0.809	0.123
Offal fat	38,625	7.488	91.061	0.205	0.102	0.012
Heart and neck sweetbreads	784	30.756	61.763	0.993	0.502	0.107
Liver	6,161	69.513	2.898	3.233	1.423	0.334
Gall	176	91.952	0.050	0.213	1.229	0.034
Spleen	1,178	77.892	1.953	2.773	1.386	0.239
Pancreas	836	59.873	24.564	2.203	1.153	0.263
Kidneys	1,037	77.660	4.867	2.347	1.051	0.199
Tongue, marketable (excl. bones)	2,153	65.843	16.199	2.610	0.870	0.157
Hair and hide	50,090	51.432	13.235	5.493	1.522	0.049
Head and tail, lean and fat	5,224	60.421	20.746	2.833	0.767	0.126
Shin and shank, lean and fat	17,420	58.949	22.573	2.707	0.772	0.133
Flank and plate, lean and fat	134,146	26.818	65.884	1.050	0.342	0.057
Rump, lean and fat	22,226	28.769	62.760	1.140	0.395	0.069
Chuck and neck, lean and fat	110,990	47.698	38.429	1.525	0.652	0.118
Round, lean	50,130	69.902	9.356	3.090	0.957	0.185
Round, fat	22,284	16.846	78.237	0.667	0.218	0.026
Loin, lean	45,996	62.557	17.934	2.863	0.851	0.163
Loin, fat	71,358	9.031	88.682	0.388	0.112	0.018

TABLE 2.—STEER 501. ANALYSIS OF SAMPLES—Continued.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Rib, lean	20,834	58.892	22.409	2.759	0.791	0.149
Rib, fat	28,322	9.697	87.439	0.401	0.134	0.020
Kidney, fat	19,544	5.462	93.311	0.190	0.067	0.011
Skeleton of feet	7,744	36.054	12.326	3.531	26.132	5.045
Skeleton of head	10,462	43.603	11.776	3.287	23.776	4.199
Skeleton of tail	304	40.880	19.185	3.481	18.055	3.155
Skeleton of shin	6,170	32.712	14.188	3.476	28.968	5.237
Skeleton of shank	7,128	26.943	22.187	3.348	27.861	5.124
Skeleton of flank and plate	7,068	40.213	15.662	3.320	18.801	3.403
Skeleton of rump	3,682	25.333	26.213	3.172	25.973	4.688
Skeleton of chuck and neck	15,778	30.106	15.495	3.656	28.381	5.205
Skeleton of round (excl. marrow)	6,978	26.646	24.351	3.086	27.253	4.948
Marrow from skeleton of round	286	10.169	88.390	0.222	0.530	0.084
Skeleton of loin	8,614	25.711	22.523	3.127	28.411	5.072
Skeleton of rib	6,388	28.428	18.371	3.322	27.868	5.181
Horns	3,354	36.989	0.633	6.469	22.743	4.167
Hoofs and dewclaws	2,523	47.011	0.658	8.453	1.715	0.143
Teeth	778	22.106	0.808	2.075	59.784	11.737

TABLE 3.—STEER 502. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	19,728	77.433	....	3.492	0.720	0.023
Circulatory system	3,446	68.285	14.513	2.586	0.679	0.138
Respiratory system	3,696	76.165	3.056	2.829	1.038	0.166
Fat from thoracic cavity	1,271	21.504	73.479	0.754	0.295	0.041
Brain and spinal cord	800	69.104	14.579	1.717	1.794	0.414
Digestive and excretory system (partial)	20,933	77.020	6.035	2.495	1.264	0.136
Offal fat	11,377	10.651	86.180	0.468	0.185	0.023
Heart andneck sweetbreads	502	59.778	25.414	2.244	1.153	0.270
Liver	3,716	68.941	1.728	3.305	1.391	0.334
Gall	241	93.020	0.043	0.208	1.027	0.029
Spleen	921	77.301	2.420	2.838	1.834	0.279
Pancreas	581	53,462	29.615	2.172	1.073	0.240
Kidneys	838	73.657	6.587	2.681	1.115	0.221
Hair and hide	39,556	57.299	3.010	6.574	0.976	0.059
Head and tail, lean and fat	4,250	64.599	14.122	3.201	0.826	0.149
Shin and shank, lean and fat	12,364	68.295	8.671	3.486	0.884	0.164
Flank and plate, lean and fat	35,594	51.905	31.222	2.583	0.696	0.119
Rump, lean and fat	8,100	56.028	25.426	2.611	0.797	0.147
Chuck and neck, lean and fat	70,744	66.333	12.728	3.072	0.921	0.158
Round, lean	44,426	72.153	4.051	3.306	0.971	0.195
Round, fat	4,620	26.602	62.837	1.549	0.322	0.038
Loin, lean	35,104	69.877	8.126	3.193	0.975	0.199
Loin, fat	9,144	15.490	78.182	1.047	0.249	0.036
Rib, lean	18,256	66.358	10.116	3.068	0.893	0.164
Rib, fat	3,338	20.655	69.994	1.484	0.281	0.051
Kidney, fat	2,916	7.388	89.667	0.420	0.241	0.039
Skeleton of feet	6,982	38.632	12.205	3.788	23.868	4.240
Skeleton of head	9,577	48.757	8.378	3.185	20.196	3.460
Skeleton of tail	441	40.425	22.573	3.251	15.075	2.733
Skeleton of shin	5,490	27.399	19.319	3.532	29.466	5.252
Skeleton of shank	5,978	27.197	24.585	3.454	25.363	4.505
Skeleton of flank and plate	5,590	41.156	12.997	3.382	21.818	3.861
Skeleton of rump	2,362	25.436	29.734	3.026	23.684	4.232
Skeleton of chuck and neck	15,092	30.767	18.259	3.407	27.553	4.918
Skeleton of round (excl. marrow)	6,296	26.477	26.444	2.996	26.259	4.681
Marrow from skeleton of round	408	7.876	90.632	0.202	0.413	0.074
Skeleton of loin	7,866	26.290	26.514	3.149	25.839	4.569
Skeleton of rib	5,290	30.433	20.599	3.647	24.864	4.401
Horns*	1,949	....	....	....	....	....
Hoofs and dewclaws	2,010	58.684	0.572	6.625	1.186	0.120
Teeth	1,038	36.211	1.025	1.632	50.004	9.483

*This sample was lost before analysis.

TABLE 4.—STEER 503. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	13,058	82.780	0.110	2.708	0.336	0.076
Circulatory system	1,782	36.244	54.914	1.249	0.329	0.060
Lean heart	1.063	78.139	3.736	2.591	0.951	0.207
Respiratory system	2,549	78.706	3.155	2.654	0.976	0.207
Brain and spinal cord	666	73.106	16.109	1.682	1.549	0.394
Digestive and excretory system (partial)	8,761	72.710	11.013	2.375	1.012	0.208
Offal fat	7,385	14.642	81.920	0.521	0.182	0.035
Liver	3,646	68.680	5.266	2.995	1.284	0.334
Kidneys	655	71.360	11.795	2.414	1.041	0.225
Stomach	5,765	77.658	6.925	2.211	1.085	0.207
Tongue, marketable	789	69.328	13.263	2.535	0.827	0.170
Hair and hide	23,008	67.765	2.570	4.793	0.979	0.066
Shin, shank, head and tail, lean and fat	8,614	69.707	10.223	3.196	0.847	0.168
Flank and plate, lean and fat	16,290	56.518	25.666	2.742	0.748	0.136
Chuck and neck, lean and fat	31,934	68.526	12.574	2.954	0.870	0.171
Round and rump, lean	25,022	73.087	4.805	3.370	1.024	0.204
Round and rump, fat	3,400	22.450	70.130	1.212	0.287	0.048
Loin, lean	17,206	70.994	8.451	3.187	0.983	0.190
Loin, fat	5,746	15.748	79.917	0.777	0.190	0.035
Rib, lean	8,932	69.677	10.231	3.154	0.927	0.185
Rib, fat	840	23.294	66.936	1.481	0.318	0.061
Kidney, fat	2,126	8.676	89.467	0.340	0.125	0.027
Skeleton	41,122	38.277	15.059	3.104	23.704	4.378
Horns, hoofs and dewclaws	1,058	46.286	2.032	7.576	6.055	0.661
Teeth	253	23.299	0.525	2.252	58.876	11.280

TABLE 5.—STEER 504. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	21,005	78.650	....	3.334	0.387	0.022
Circulatory system	1,637	28.710	63.730	1.112	0.405	0.041
Lean heart	1,428	76.650	4.310	2.774	1.015	0.203
Respiratory system	3,628	67.410	14.900	2.882	0.974	0.181
Brain and spinal cord	724	69.230	15.080	1.788	1.358	0.350
Digestive and excretory system (partial)	17,569	68.540	18.040	1.910	0.726	0.145
Offal fat	25,105	12.760	84.820	0.334	0.147	0.023
Liver	4,754	69.220	2.436	3.275	1.352	0.358
Kidneys	877	69.480	12.810	2.452	1.058	0.219
Stomachs	12,820	79.670	8.040	1.701	0.897	0.151
Tongue, marketable	1,587	60.750	23.480	2.182	0.759	0.141
Hair and hide	41,144	58.290	8.070	5.522	1.057	0.043
Shin, shank, head and tail, lean and fat	16,070	60.640	20.560	2.951	0.803	0.146
Flank and plate, lean and fat	49.650	41.640	45.620	1.945	0.572	0.101
Rump, lean and fat	10,846	40.720	46.810	1.847	0.574	0.106
Chuck and neck, lean and fat	59,808	58.330	24.030	2.620	0.758	0.146
Round, lean	37,238	69.510	9.210	3.208	0.983	0.194
Round, fat	9,818	16.610	78.030	0.906	0.238	0.030
Loin lean	33 676	66.920	12.220	3.051	0.946	0.181
Loin, fat	18,340	11.620	84.910	0.532	0.162	0.025
Rib, lean	18,506	63.280	17.520	2.940	0.831	0.167
Rib, fat	6,770	14.420	80.630	0.833	0.202	0.031
Kidney, fat	11,400	4.800	93.940	0.215	0.126	0.017
Skeleton of feet, head, tail, shin and shank	23,568	36.050	13.640	3.237	27.594	5.076
Skeleton of flank and plate	4,572	44.100	18.180	3.523	15.715	2.916
Skeleton of rump	2,428	25.720	26.000	3.073	27.381	5.184
Skeleton of chuck and neck	11,176	30.180	16.270	3.524	29.162	5.344
Skeleton of round	4,808	21.880	27.470	3.120	31.049	5.755
Skeleton of loin	5,850	29.840	22.100	3.184	26.452	4.812
Skeleton of rib	5.092	32.550	16.260	3.417	27.791	5.096
Horns, hoofs and dewclaws	2,532	69.476	0.514	4.621	2.428	0.157
Teeth*	338	....	....	....	....	....

*This sample was lost before analysis.

TABLE 6.—STEER 505. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	13,810	82.260	0.351	2.726	0.329	0.023
Circulatory system	1,168	33.230	59.064	1.285	0.277	0.047
Lean heart	938	77.382	5.110	2.618	0.973	0.209
Respiratory system	2,498	76.829	5.477	2.713	0.951	0.202
Brain and spinal cord	537	73.810	14.738	1.688	1.719	0.411
Digestive and excretory system (partial)	8,258	71.893	12.815	2.476	1.053	0.226
Offal fat	12,781	12.410	85.384	0.340	0.117	0.022
Liver	3,983	68.096	5.770	3.205	1.329	0.347
Kidneys	718	75.712	7.835	2.376	1.061	0.226
Stomach	8,818	77.261	10.849	1.681	0.868	0.173
Tongue, marketable	1,115	64.061	20.160	2.352	0.759	0.156
Hair and hide	22,884	62.138	5.336	5.297	0.696	0.066
Shin, shank, head and tail, lean and fat	9,386	64.430	15.398	3.216	0.818	0.165
Flank and plate, lean and fat	24,194	43.720	42.762	2.211	0.580	0.116
Chuck and neck, lean and fat	38,344	62.294	18.949	2.886	0.830	0.165
Round and rump, lean	25,784	69.066	9.464	3.326	0.976	0.200
Round and rump, fat	5,970	14.140	80.640	0.452	0.174	0.032
Loin, lean	19,686	68.190	9.983	3.236	0.963	0.196
Loin, fat	7,558	9.333	87.547	0.535	0.127	0.024
Rib, lean	11,300	61.762	19.191	2.964	0.841	0.176
Rib, fat	2.640	10.913	85.385	0.643	0.167	0.033
Kidney, fat	5,754	5.263	93.527	0.236	0.084	0.016
Skeleton	37,745	35.792	17.555	3.186	23.852	4.403
Horns, hoofs and dewclaws	1,206	46.098	1.104	7.724	5.340	0.611
Teeth	268	21.938	0.634	2.264	59.386	10.697

TABLE 7.—STEER 507. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	20,316	78.174	....	3.431	0.670	0.022
Circulatory system	4,278	47.118	41.273	1.695	0.535	0.104
Respiratory system	3,768	77.467	3.927	2.729	0.954	0.169
Brain and spinal cord	744	70.806	13.738	1.498	1.749	0.418
Digestive and excretory system	27,417	70.515	14.079	2.097	0.825	0.150
Offal fat	11,037	13.096	83.962	0.412	0.140	0.029
Hair and hide	34,473	60.845	6.213	5.688	1.065	0.049
Head and tail, lean and fat	4,038	62.582	18.949	2.841	0.895	0.161
Shin and shank, lean and fat	11.860	69.883	7.860	3.343	0.922	0.167
Flank and plate, lean and fat	36,130	51.939	32.362	2.504	0.693	0.124
Rump, lean and fat	7,736	50.803	31.644	2.275	0.721	0.139
Chuck and neck, lean and fat	62,530	65.569	15.166	2.891	0.862	0.157
Round, lean	39,302	72.727	5.772	3.230	0.981	0.192
Round, fat	5,378	24.446	68.671	1.093	0.276	0.039
Loin, lean	29,724	70.696	8.096	3.128	0.972	0.185
Loin, fat	10,188	17.822	76.684	0.826	0.223	0.039
Rib, lean	15,788	67.438	12.239	2.999	0.937	0.174
Rib, fat	2,432	17.554	76.436	0.947	0.253	0.042
Kidney, fat	4,376	6.784	91.300	0.284	0.147	0.025
Skeleton of feet, head and tail	15,275	42.804	11.776	3.456	23.906	3.858
Skeleton of shin and shank	10,350	23.960	19.357	3.646	33.717	4.634
Skeleton of flank and plate	6,278	44.217	13.485	3.380	18.472	2.851
Skeleton of rump	2,536	25.041	26.339	3.229	25.836	3.940
Skeleton of chuck and neck	13,202	31.983	15.245	3.555	25.644	4.204
Skeleton of round	5,864	26.093	29.961	3.142	23.204	4.161
Skeleton of loin	6,506	26.630	26.891	2.866	26.102	3.724
Skeleton of rib	5,050	28.673	18.021	3.363	28.739	4.282
Horns	1,600	41.605	0.624	5.762	21.877	3.960
Hoofs and dewclaws	1,490	54.438	1.143	7.002	2.044	0.163
Teeth	712	26.534	1.027	1.964	56.717	10.889

TABLE 8.—STEER 509. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	18,291	78.053	....	3.429	0.686	0.023
Circulatory system	2,616	69.945	12.261	2.590	0.922	0.167
Respiratory system	3,233	77.032	2.879	3.004	1.011	0.176
Fat from thoracic cavity	1,248	19.808	76.095	0.720	0.297	0.043
Brain and spinal cord	739	66.874	17.662	1.679	1.576	0.379
Digestive and excretory system (partial)	19,016	73.011	11.886	2.206	0.908	0.123
Offal fat	9,922	11.360	85.888	0.534	0.175	0.024
Heart and neck sweetbreads	630	50.304	37.140	1.816	1.039	0.254
Liver	3,875	68.408	1.757	3.088	1.334	0.326
Gall	110	91.529	0.059	0.250	0.874	0.031
Spleen	1,304	77.255	2.126	2.993	1.420	0.242
Pancreas	562	54.915	28.448	2.239	1.178	0.269
Kidneys	774	77.013	3.823	2.649	1.115	0.234
Hair and hide	37,614	58.969	2.477	6.270	1.024	0.046
Head and tail, lean and fat	3,212	66.769	13.022	3.077	0.821	0.150
Shin and shank, lean and fat	11,782	67.912	9.765	3.380	0.911	0.167
Flank and plate, lean and fat	31,790	53.639	28.926	2.620	0.733	0.145
Rump, lean and fat	7,370	55.813	26.599	2.628	0.804	0.146
Chuck and neck, lean and fat	60,176	68.493	9.856	3.076	0.895	0.166
Round, lean	40,376	73.647	4.183	3.223	1.005	0.196
Round, fat	5,106	25.559	64.040	1.621	0.343	0.041
Loin, lean	30,836	69.632	9.010	3.103	0.951	0.180
Loin, fat	7,570	16.259	77.561	1.033	0.253	0.041
Rib, lean	16,360	67.795	10.844	2.927	0.915	0.170
Rib, fat	1,978	17.552	76.022	1.058	0.279	0.045
Kidney, fat	1,576	5.466	92.412	0.314	0.138	0.017
Skeleton of feet	6,144	41.075	10.778	3.669	23.457	4.245
Skeleton of head	8,247	47.540	8.478	3.176	21.164	3.772
Skeleton of tail	386	37.947	26.555	2.873	15.105	2.734
Skeleton of shin	5,046	28.351	18.203	3.839	29.339	5.168
Skeleton of shank	5,498	28.550	22.558	3.519	26.144	5.027
Skeleton of flank and plate	5,124	41.367	13.032	3.533	22.382	4.082
Skeleton of rump	2,860	26.895	29.745	3.058	22.246	3.878
Skeleton of chuck and neck	13,682	32.387	17.293	3.704	25.046	4.606
Skeleton of round (excl. marrow)	5,442	27.956	24.660	2.967	25.948	4.624
Marrow from skeleton of round	578	11.658	86.848	0.203	0.370	0.058
Skeleton of loin	6,872	27.517	25.661	3.130	25.647	4.414
Skeleton of rib	4,986	28.050	16.791	3.623	30.569	5.444
Hoofs and dewclaws	1,590	66.980	0.459	5.193	1.457	0.117
Teeth	838	28.535	0.535	1.740	56.001	10.533

TABLE 9.—STEER 512. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	24,176	79.949	0.055	3.073	0.790	0.023
Circulatory system	2,432	40.529	47.983	1.710	0.563	0.055
Lean heart	1,555	77.321	3.470	2.803	1.269	0.215
Respiratory system	3,881	75.487	4.670	2.803	1.079	0.164
Fat from thoracic cavity	1,171	12.232	85.522	0.263	0.144	0.015
Brain and spinal cord	666	72.058	11.117	1.687	1.871	0.385
Digestive and excretory system (partial)	20,735	73.684	10.288	2.183	0.761	0.119
Offal fat	17,454	11.212	86.273	0.369	0.144	0.019
Heart and neck sweetbreads	511	40.399	49.421	1.497	0.733	0.168
Liver	4,416	68.984	2.625	3.263	1.588	0.334
Gall	212	93.144	0.033	0.223	1.039	0.028
Spleen	1,255	77.145	2.366	2.800	1.339	0.239
Pancreas	736	57.391	26.641	2.087	1.326	0.274
Kidneys	1,074	77.235	6.831	2.080	1.053	0.203
Tongue, marketable	1,766	66.379	13.428	2.580	0.899	0.161
Hair and hide	41,268	56.193	3.612	6.547	1.163	0.047
Head and tail, lean and fat	4,412	61.554	19.074	2.893	0.859	0.139
Shin and shank, lean and fat	12,706	68.606	9.380	3.343	0.927	0.161
Flank and plate, lean and fat	48,946	41.914	45.337	1.910	0.570	0.094
Rump, lean and fat	10,484	44.598	41.829	2.027	0.667	0.119
Chuck and neck, lean and fat	73,512	63.188	18.191	2.826	0.919	0.150
Round, lean	43,408	73.272	4.557	3.237	1.024	0.192
Round, fat	9,940	22.030	70.658	0.765	0.311	0.040
Loin, lean	32,062	67.607	11.040	3.076	0.912	0.170
Loin, fat	15,308	12.497	83.354	0.650	0.180	0.026
Rib, lean	16,908	65.119	14.950	2.967	0.896	0.157
Rib, fat	5,398	14.938	80.367	0.840	0.212	0.035

TABLE 9.—STEER 512. ANALYSIS OF SAMPLES—Continued.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Kidney, fat	4,740	4.482	93.915	0.183	0.130	0.020
Skeleton of feet	7,016	37.452	14.314	3.597	24.365	4.405
Skeleton of head	9,665	43.142	12.955	3.229	22.420	4.204
Skeleton of tail	416	36.970	24.279	3.129	18.107	3.265
Skeleton of shin	6,074	27.159	20.808	3.631	29.984	5.388
Skeleton of shank	6,156	31.979	21.541	3.540	22.768	4.094
Skeleton of flank and plate	7,788	36.792	21.061	3.033	19.564	3.586
Skeleton of rump	3,264	23.678	30.680	2.986	26.274	4.446
Skeleton of chuck and neck	16,536	28.775	18.986	3.244	30.510	5.438
Skeleton of round (excl. marrow)	7,430	28.723	26.734	2.822	22.605	4.058
Marrow from skeleton of round	396	10.084	88.297	0.186	0.657	0.132
Skeleton of loin	8,748	25.136	24.403	2.987	26.642	5.334
Skeleton of rib	6,938	29.436	16.324	3.475	28.699	5.454
Horns	1,810	35.228	0.480	7.033	22.746	3.874
Hoofs and dewclaws	1,724	48.902	0.588	7.857	2.791	0.124
Teeth	710	19.913	0.782	2.152	63.721	12.031

TABLE 10.—STEER 513. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	25,680	77.676	....	3.341	0.722	0.028
Circulatory system	3,485	77.600	4.500	2.673	0.909	0.157
Respiratory system	4,858	73.905	7.032	2.742	0.992	0.155
Fat from thoracic cavity	3,942	13.440	83.707	0.366	0.185	0.024
Brain and spinal cord	748	68.192	15.496	1.724	1.601	0.410
Digestive and excretory system (partial)	25,642	75.309	7.697	2.310	1.041	0.157
Offal fat	53,771	5.683	92.874	0.215	0.079	0.011
Heart and neck sweetbreads	1,334	40.327	50.545	1.405	0.824	0.198
Liver	5,920	67.926	3.126	3.225	1.397	0.333
Gall	37	91.391	0.146	0.312	1.191	0.035
Spleen	1,114	75.645	4.542	2.932	1.253	0.242
Pancreas	873	50.118	34.657	1.868	1.088	0.242
Kidneys	1,015	76.071	5.802	2.503	1.133	0.220
Hair and hide	45,286	57.566	10.072	5.178	0.941	0.054
Head and tail, lean and fat	5,390	56.379	26.291	2.439	0.770	0.128
Shin and shank, lean and fat	17,798	55.759	27.657	2.309	0.697	0.118
Flank and plate, lean and fat	115,774	29.221	62.259	1.242	0.385	0.065
Rump, lean and fat	19,082	31.575	58.755	1.378	0.438	0.080
Chuck and neck, lean and fat	110,940	47.879	37.191	2.152	0.629	0.116
Round, lean	50,782	65.159	14.337	2.901	0.911	0.173
Round, fat	19,108	17.763	76.089	0.921	0.199	0.024
Loin, lean	44,510	59.396	21.597	2.777	0.826	0.163
Loin, fat	49,928	8.901	88.492	0.366	0.115	0.018
Rib, lean	24,744	55.589	27.713	2.567	0.757	0.142
Rib, fat	23,608	17.797	75.455	0.408	0.138	0.021
Kidney, fat	14,490	3.912	94.928	0.156	0.074	0.010
Skeleton of feet	7,598	36.238	14.856	3.522	23.836	4.243
Skeleton of head	7,865	40.707	9.440	3.300	25.028	5.856
Skeleton of tail	297	39.282	19.765	3.353	17.252	3.031
Skeleton of shin	6,120	29.290	17.835	3.377	27.325	4.811
Skeleton of shank	6,058	26.124	19.919	3.570	29.591	5.233
Skeleton of flank and plate	7,438	40.922	15.081	3.278	20.425	4.139
Skeleton of rump	3,464	24.417	29.288	3.009	24.688	4.683
Skeleton of chuck and neck	15,526	32.008	17.781	3.508	25.202	5.058
Skeleton of round (excl. marrow)	6,564	24.756	30.638	2.968	24.757	4.366
Marrow from skeleton of round	480	8.660	89.964	0.161	0.811	0.139
Skeleton of loin	8,536	25.186	29.799	3.025	24.383	4.699
Skeleton of rib	7,096	26.559	21.539	3.363	29.216	5.528
Horns	2,144	36.851	0.766	6.450	22.622	4.168
Hoofs and dewclaws	2,180	41.930	0.890	8.956	2.960	0.239
Teeth	874	31.897	1.103	1.811	52.576	9.959

Table 11.—Steer 515. Analysis of Samples.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	27,856	79.107	....	3.217	0.594	0.024
Circulatory system	5,787	42.032	48.530	1.276	0.480	0.086
Respiratory system	3,653	76.354	5.443	2.699	0.968	0.187
Brain and spinal cord	728	70.038	16.091	1.654	1.634	0.395
Digestive and excretory system	36.311	66.167	18.711	2.019	1.851	0.162
Offal fat	29,877	7.532	90.291	0.281	0.124	0.015
Hair and hide	49,943	56.003	12.550	4.840	1.857	0.059
Head and tail, lean and fat	5,918	53.562	30.538	2.417	0.731	0.130
Shin and shank, lean and fat	16,676	57.361	26.753	2.502	0.716	0.123
Flank and plate, lean and fat	87,138	31.118	59.929	1.360	0.388	0.071
Rump, lean and fat	15,810	35.336	54.204	1.506	0.476	0.085
Chuck and neck, lean and fat	88,134	53.265	31.088	2.356	0.712	0.126
Round, lean	42,942	67.691	11.052	3.102	0.924	0.177
Round, fat	19,058	17.522	77.696	0.784	0.215	0.026
Loin, lean	41,620	64.691	15.193	2.999	0.994	0.181
Loin, fat	38,324	10.576	86.623	0.412	0.115	0.017
Rib, lean	19,016	61.183	20.387	2.776	0.849	0.152
Rib, fat	16.282	9.071	88.287	0.394	0.134	0.020
Kidney, fat	9,922	4.951	94.433	0.178	0.081	0.015
Skeleton of feet, head and tail	18,179	41.368	11.161	3.032	23.490	4.066
Skeleton of shin and shank	13.900	27.713	27.063	3.045	24.670	4.032
Skeleton of flank and plate	6,368	42.196	15.964	3.410	17.779	3.113
Skeleton of rump	4,074	29.793	25.690	3.096	23.313	4.071
Skeleton of chuck and neck	14,528	30.500	15.517	3.333	29.568	4.253
Skeleton of round	6,344	23.643	29.413	3.024	28.767	4.890
Skeleton of loin	7,784	25.307	28.219	2.971	26.216	4.497
Skeleton of rib	6,464	26.086	20.159	3.270	31.176	4.374
Horns	1,804	40.640	0.591	5.617	23.674	4.223
Hoofs and dewclaws	1,893	53.752	0.529	7.363	1.823	0.072
Teeth	786	27.331	0.859	1.785	57.132	10.992

Table 12.—Steer 523. Analysis of Samples.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	15,287	80.520	....	2.790	0.659	0.022
Circulatory system	3,044	53.054	35.823	1.684	0.598	0.110
Respiratory system	3,371	78.769	4.054	2.605	0.986	0.189
Brain and spinal cord	797	68.595	17.610	1.616	1.515	0.359
Digestive and excretory system	24,667	75.194	10.339	2.190	0.788	0.158
Hair and nide	33.097	62.801	1.150	5.603	1.030	0.051
Head and tail, lean and fat	3,100	68.166	11.573	3.094	0.923	0.154
Shin and shank, lean and fat	8,684	71.786	6.036	3.402	0.915	0.169
Flank and plate, lean and fat	26,984	59.510	22.920	2.693	0.739	0.139
Rump, lean and fat	5.418	54.330	29.269	2.532	0.748	0.154
Chuck and neck, lean and fat	50,320	70.884	10.288	2.986	0.921	0.171
Round, lean	33,900	76.929	2.310	3.155	1.042	0.202
Loin, lean	25,834	69.754	10.406	3.027	0.921	0.172
Rib, lean	12.032	70.282	9.297	3.119	0.927	0.178
Round, fat	4,556	29.544	60.224	1.580	0.357	0.048
Loin, fat	6,376	16.497	77.934	0.863	0.281	0.045
Rib, fat	1,522	23.543	64.977	1.511	0.394	0.059
Kidney, fat	3,110	5.259	92.726	0.465	0.179	0.015
Offal, fat	7,915	15.418	81.284	0.495	0.204	0.030
Skeleton of feet, head and tail	13,120	44.251	8.120	3.563	22.796	4.135
Skeleton of shin and shank	8,862	29.464	20.364	3.381	27.635	5.132
Skeleton of flank and plate	3,882	44.868	10.710	3.471	19.443	3.467
Skeleton of rump	1,770	27.036	20.259	3.270	29.591	5.430
Skeleton of chuck and neck	9,876	33.866	12.894	3.681	29.394	5.391
Skeleton of round	4.630	39.850	26.599	1.942	20.522	3.840
Skeleton of loin	5,322	27.873	23.686	3.145	27.029	4.981
Skeleton of rib	3,844	31.218	12.517	3.592	31.713	5.769
Horns	1,167	46.232	0.625	5.616	18.740	3.416
Hoofs and dewclaws*	1,063	....	....	....	....	....
Teeth	766	26.317	0.763	2.098	56.395	10.676

*This sample was lost before analysis.

TABLE 13.—STEER 524. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	17,019	82.006	....	2.787	0.746	0.022
Circulatory system	2,953	62.090	22.418	2.240	0.768	0.132
Respiratory system	3,455	77.635	2.601	2.793	1.073	0.178
Brain and spinal cord	758	73.218	10.255	1.597	1.418	0.338
Digestive and excretory system (partial)	17,924	74.094	9.821	2.303	0.885	0.150
Offal fat	5,007	25.069	69.444	0.760	0.320	0.035
Heart and neck sweetbreads	541	75.123	7.448	2.603	1.873	0.463
Liver	3.019	69.840	3.316	3.047	1.408	0.327
Gall	229	94.859	0.092	0.167	0.794	0.031
Spleen	757	78.752	1.819	2.750	1.335	0.260
Pancreas	435	65.634	15.877	2.540	1.230	0.285
Kidneys	766	76.830	5.735	2.433	1.158	0.208
Hair and hide	30,092	59.259	1.813	6.300	1.577	0.058
Head and tail, lean and fat	3,364	66.261	13.126	3.127	1.026	0.179
Shin and shank, lean and fat	8,674	73.037	5.601	2.925	0.974	0.166
Flank and plate, lean and fat	19,788	63.711	15.372	3.200	0.952	0.154
Rump, lean and fat	4,030	63.611	17.147	2.957	0.972	0.175
Chuck and neck, lean and fat	46,386	72.555	6.292	3.160	0.975	0.174
Round, lean	37,714	76.864	2.716	3.257	1.043	0.192
Round, fat	2,526	36.260	49.962	2.237	0.420	0.053
Loin, lean	24,200	72.680	4.544	3.310	1.057	0.194
Loin, fat	2,444	18.811	73.319	1.237	0.350	0.053
Rib, lean and fat	13,144	70.285	7.949	3.310	0.982	0.182
Kidney, fat	766	11.440	84.187	0.440	0.179	0.031
Skeleton of feet	6,010	40.508	13.002	3.592	24.515	4.375
Skeleton of head and tail	8,318	45.930	10.389	3.053	23.867	4.263
Skeleton of shin and shank	10,262	31.581	19.317	3.365	25.920	4.619
Skeleton of flank and plate	5,926	43.358	15.272	3.211	19.164	3.345
Skeleton of rump	2,424	34.304	21.452	2.997	22.395	4.057
Skeleton of chuck and neck	12,896	40.299	15.844	3.316	21.786	3.986
Skeleton of round	5.878	31.056	28.341	2.666	22.700	4.063
Skeleton of loin	6,586	29.252	26.901	2.845	24.306	4.246
Skeleton of rib	5,310	35.735	18.535	2.969	24.951	4.429
Horns*	1,227	....	....	....	....	....
Hoofs and dewclaws	1,494	50.239	0.832	7.553	3.194	0.219
Teeth	806	26.967	1.106	1.907	57.863	10.988

*This sample was lost before analysis.

TABLE 14.—STEER 525. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	13,614	80.514	....	2.942	0.660	0.026
Circulatory system	1,320	64.087	24.542	1.705	0.715	0.121
Respiratory system	1,658	78.612	2.633	2.823	1.111	0.193
Brain and spinal cord	711	71.054	13.931	1.737	1.504	0.370
Digestive and excretory system	23,001	77.479	9.144	1.999	0.883	0.156
Hair and hide	27,813	62.396	0.498	5.724	1.331	0.157
Head and tail, lean and fat	2,788	74.319	13.082	1.858	0.986	0.158
Shin and shank, lean and fat	7,596	72.849	5.330	3.337	0.965	0.177
Flank amd plate, lean and fat	18,762	60.827	20.204	2.873	0.828	0.149
Rump, lean and fat	4,154	60.691	20.925	2.760	0.864	0.162
Chuck and neck, lean and fat	35,824	71.151	8.443	3.125	0.949	0.178
Round, lean	27,524	77.034	2.403	3.120	1.064	0.205
Loin, lean	18,710	74.634	3.469	3.237	1.048	0.200
Rib, lean	11,666	70.514	8.659	3.161	0.977	0.181
Round, fat	1,962	32.685	56.826	1.599	0.433	0.056
Loin, fat	3,758	22.002	69.589	1.099	0.294	0.040
Rib, fat	664	28.087	61.613	1.611	0.605	0.092
Kidney, fat	1,258	6.721	90.181	0.470	0.161	0.020
Offal, fat	4,961	21.028	70.641	1.286	0.293	0.051
Skeleton of feet, head and tail	10,782	43.021	9.990	3.736	21.822	4.171
Skeleton of shin and shank	7,014	30.333	19.135	3.485	29.526	4.190
Skeleton of flank and plate	3,454	44.613	10.853	3.365	21.567	2.989
Skeleton of rump	1,542	30.800	23.819	3.234	24.612	4.216
Skeleton of chuck and neck	8,450	34.145	19.714	3.092	22.900	4.301
Skeleton of round	4,046	28.602	32.687	2.653	21.783	2.826
Skeleton of loin	3,928	28.594	25.309	3.020	24.434	3.678
Skeleton of rib	3,888	31.735	18.050	3.593	24.740	4.352
Horns	1,298	48.873	0.543	5.641	16.718	3.141
Hoofs and dewclaws	940	51.906	0.575	7.892	1.259	0.134
Teeth	690	23.125	1.063	1.903	60.713	11.737

TABLE 15.—STEER 526. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	18,957	79.926	....	3.087	0.777	0.025
Circulatory system	2,413	63.316	21.434	2.343	0.814	0.145
Respiratory system	3,797	76.615	3.288	2.800	1.025	0.156
Fat from the thoracic cavity	1,585	21.467	73.139	0.753	0.286	0.034
Brain and spinal cord	660	73.217	10.255	1.747	1.728	0.420
Digestive and excretory system (partial)	20,541	72.884	12.222	2.130	0.768	0.127
Offal fat	11,551	12.992	84.144	0.410	0.175	0.018
Heart and neck sweetbreads	439	60.467	24.213	2.253	1.444	0.348
Liver	3,531	67.922	4.255	3.247	1.469	0.348
Gall	143	92.398	0.138	0.230	1.158	0.031
Spleen	831	78.490	1.496	2.767	1.554	0.297
Pancreas	498	63.457	18.209	2.245	1.172	0.282
Kidneys	922	73.557	9.071	2.353	1.069	0.198
Hair and hide	35,732	57.828	5.714	5.923	1.440	0.050
Head and tail, lean and fat	3.616	61.791	19.640	2.910	0.832	0.142
Shin and shank, lean and fat	11,644	70.950	7.537	3.301	0.900	0.164
Flank and plate, lean and fat	39,524	49.492	35.249	2.330	0.678	0.125
Rump, lean and fat	8,594	53.663	29.882	2.463	0.736	0.138
Chuck and neck, lean and fat	61,228	65.441	14.500	2.923	0.907	0.166
Round, lean	44,614	66.884	11.887	3.300	1.031	0.191
Round, fat	5,016	22.666	63.981	1.670	0.284	0.036
Loin, lean	31,440	71.948	5.341	3.210	1.018	0.190
Loin, fat	11.634	14.508	79.929	0.850	0.208	0.030
Rib, lean	17,264	69.641	10.014	3.077	0.920	0.165
Rib, fat	3,720	17.241	74.768	1.160	0.259	0.044
Kidney, fat	3,224	9.074	87.831	0.340	0.137	0.021
Skeleton of feet	6.138	38.425	13.853	3.682	23.475	4.354
Skeleton of head and tail	9.165	46.363	12.805	2.998	21.004	3.832
Skeleton of shin and shank	11,612	27.802	20.097	3.254	28.703	5.238
Skeleton of flank and plate	6,588	40.154	16.466	3.175	20.333	3.793
Skeleton of rump	2.838	29.344	25.608	3.108	23.706	4.277
Skeleton of chuck and neck	13,842	34.313	17.449	3.339	24.601	4.482
Skeleton of round	6,352	27.057	30.272	2.694	23.272	4.318
Skeleton of loin	6.844	29.163	28.333	2.826	23.314	4.282
Skeleton of rib	5,690	31.712	20.075	3.314	26.287	4.758
Horns	1,427	41.315	0.744	6.411	19.354	3.592
Hoofs and dewclaws	1,875	54.392	0.625	7.294	2.123	0.085
Teeth	782	22.147	1.273	1.941	61.470	11.686

TABLE 16.—STEER 527. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	27,382	78.941	....	3.283	0.762	0.023
Circulatory system	4.903	53.951	32.798	1.927	0.635	0.114
Respiratory system	4,326	73.330	7.186	2.717	1.024	0.166
Fat from thoracic cavity	3,988	10.340	87.646	0.335	0.128	0.015
Brain and spinal cord	701	69.957	14.059	1.583	1.544	0.368
Digestive and excretory system (partial)	23,818	66.822	18.527	2.077	0.710	0.119
Offal fat	48,517	5.394	93.260	0.183	0.118	0.013
Heart and neck sweetbreads	1,037	36.622	55.347	1.187	0.734	0.308
Liver	5,720	67.872	3.472	3.293	1.575	0.184
Spleen	1,226	76.790	2.169	2.903	1.282	0.237
Pancreas	849	41.574	46.296	1.460	0.887	0.203
Kidneys	1,244	75.345	8.280	2.210	1.001	0.193
Hair and hide	46,240	54.475	11.859	5.317	1.369	0.056
Head and tail, lean and fat	5,018	53.921	30.635	2.410	0.691	0.123
Shin and shank, lean and fat	17,358	56.503	26.398	2.570	0.754	0.130
Flank and plate, lean and fat	118.978	27.200	65.491	1.097	0.312	0.059
Rump, lean and fat	24,020	29.026	62.962	1.233	0.315	0.059
Chuck and neck, lean and fat	112.440	46.782	39.316	2.030	0.617	0.109
Round, lean	51.396	66.109	13.931	2.993	0.864	0.175
Round, fat	21,466	16.129	79.323	0.753	0.204	0.022
Loin, lean	50.140	61.192	20.496	2.797	0.849	0.161
Loin, fat	52,724	9.519	88.271	0.357	0.127	0.017
Rib, lean	25,860	54.984	28.098	2.547	0.737	0.141
Rib, fat	24.278	9.463	88.208	0.407	0.133	0.016
Kidney, fat	18.964	5.423	93.227	0.187	0.102	0.014
Skeleton of feet	7,442	37.280	16.115	3.372	23.664	3.849
Skeleton of head and tail	8,822	42.136	24.822	3.165	21.749	3.676
Skeleton of shin and shank	13,136	27.256	21.276	3.149	28.369	4.550
Skeleton of flank and plate	6,082	39.334	18.437	2.996	19.531	3.404
Skeleton of rump	3.260	24.846	30.690	2.967	23.925	3.747
Skeleton of chuck and neck	14,870	28.058	24.570	3.082	25.037	3.944
Skeleton of round	6,446	20.998	33.954	2.642	27.032	4.964
Skeleton of loin	7,140	25.920	25.782	3.151	26.949	5.156
Skeleton of rib	6,546	26.920	23.074	3.022	28.622	5.503
Horns	1,266	35.662	0.775	6.950	19.811	3.658
Hoofs and dewclaws	2,174	44.082	0.959	8.916	2.059	0.145
Teeth	872	20.697	1.438	1.954	63.378	11.767

TABLE 17.—STEER 531. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	9.457	81.882	....	2.841	0.703	0.040
Circulatory system	1,971	56.721	29.318	1.968	0.676	0.126
Respiratory system	1,915	78.338	2.818	2.680	1.054	0.204
Brain and spinal cord	573	72.987	13.498	1.765	1.502	0.363
Digestive and excretory system (partial)	11,807	77.129	9.230	1.977	0.669	0.121
Offal fat	2,899	25.931	70.680	0.621	0.290	0.046
Heart and neck sweetbreads	472	67.988	14.791	2.497	1.720	0.427
Liver	2,205	71.785	1.945	2.921	1.385	0.321
Gall	86	91.678	....	0.214	0.978	0.052
Spleen	481	75.079	4.195	2.958	1.440	0.291
Pancreas	297	67.078	14.763	2.508	1.229	0.288
Kidneys	506	75.079	8.283	2.265	1.042	0.213
Hair and hide	16,693	63.665	0.811	5.733	1.136	0.075
Head and tail, lean and fat	1,722	67.218	14.073	2.923	0.872	0.155
Shin and shank, lean and fat	5,480	71.792	4.736	3.596	1.071	0.188
Flank and plate, lean and fat	10.854	60.374	17.191	3.055	1.005	0.176
Rump, lean and fat	2,506	61.990	18.113	2.980	0.976	0.177
Chuck and neck, lean and fat	26,902	69.914	7.805	3.274	1.034	0.196
Round, lean	21,496	75.102	1.831	3.272	1.102	0.208
Round, fat	1,490	28.477	60.684	1.524	0.478	0.071
Loin, lean	14 078	73.011	4.278	3.312	1.100	0.204
Loin, fat	2.264	24.756	64.861	1.386	0.439	0.075
Rib, lean and fat	6 612	69.536	7.559	3.338	1.052	0.190
Kidney fat	726	6.066	90.265	0.596	0.240	0.031
Skeleton of feet	3,762	39.773	14.354	3.233	24.642	4.432
Skeleton of head and tail	4.842	51.145	8.071	3.041	20.849	3.629
Skeleton of shin and shank	5.998	31.730	18.346	2.937	27.416	5.113
Skeleton of flank and plate	2,546	46.771	10.571	3.220	20.395	3.464
Skeleton of rump	1.060	31.418	21.238	3.274	25.533	4.573
Skeleton of chuck and neck	6,098	37.493	16.015	3.536	23.526	4.187
Skeleton of round	3.640	35.030	25.913	2.679	21.363	3.806
Skeleton of loin	2.834	31.090	21.915	3.298	25.494	4.471
Skeleton of rib	2.280	32.384	16.742	3.738	25.229	4.587
Hoofs and dewclaws	790	52.103	0.827	7.587	1.963	0.125
Teeth	426	27.423	0.882	1.990	55.799	10.625

TABLE 18.—STEER 532. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	18,752	80.473	....	2.997	0.652	0.033
Circulatory system	4,483	47.915	40.256	1.605	0.566	0.105
Respiratory system	3,870	77.557	3.413	2.636	1.052	0.193
Brain and spinal cord	643	72.457	14.458	1.658	1.622	0.392
Digestive and excretory system (partial)	21,741	72.701	13.979	1.898	0.708	0.134
Offal fat	23,697	9.552	88.805	0.243	0.116	0.016
Heart and neck sweetbreads	441	49.463	38.461	1.629	0.986	0.238
Liver	5,694	71.419	2.375	2.843	1.375	0.307
Gall	185	92 254	....	0.220	1.005	0.043
Spleen	884	74.698	5.033	2.888	1.256	0.262
Pancreas	630	56.164	27.676	2.032	1.180	0.293
Kidneys	868	71.247	10.983	2.521	1.019	0.213
Hair and hide	33,988	59.564	6.839	5.225	1.032	0.071
Head and tail, lean and fat	4,260	60.370	21.950	2.687	0.807	0.146
Shin and shank, lean and fat	12,008	67.536	10.998	3.160	0.933	0.167
Flank and plate, lean and fat	44,636	43.753	41.749	2.237	0.655	0.116
Rump, lean and fat	8.058	48.528	35.883	2.345	0.716	0.133
Chuck and neck, lean and fat	66,204	61.792	18.520	2.910	0.899	0.156
Round, lean	38.064	71.904	5.223	3.304	1.065	0.200
Round, fat	6.064	21.714	70.321	1.113	0.295	0.042
Loin, lean	36,136	68.406	9.593	3.252	1.004	0.184
Loin, fat	14,954	12.520	83.405	0.674	0.191	0.033
Rib, lean	17,356	67.280	11.483	3.156	0.979	0.176
Rib, fat	6.194	15.622	78.878	0.852	0.268	0.040
Kidney fat	11,734	3.271	95.229	0.150	0.085	0.022
Skeleton of feet	6.490	39.080	14.349	3.607	23.845	4.221
Skeleton of head and tail	7.120	46.409	12.787	2.985	21.246	3.794
Skeleton of shin and shank	10.756	28.890	21.617	4.316	23.357	4.397
Skeleton of flank and plate	5.478	44.408	18.946	3.027	14.958	2.738
Skeleton of rump	2.282	28.899	27.742	3.205	22.689	4 084
Skeleton of chuck and neck	13.014	30.283	23.624	3.367	24 027	4.351
Skeleton of round	5.624	26.867	34.032	2.514	20.794	3.713
Skeleton of loin	6.246	28.097	29.257	3.093	22.053	4 074
Skeleton of rib	5.222	34.969	22.509	2.951	22.280	4.009
Horns	228	54.753	0.511	6.327	7.572	1.439
Hoofs and dewclaws	1,406	51.936	0.646	7.653	1.948	0.153
Teeth	494	31.017	0.882	2.145	51.709	10.154

TABLE 19.—STEER 538. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	7,219	82.400	0.097	2.735	0.786	0.028
Circulatory system	1.670	55.482	28.703	1.934	0.632	0.114
Respiratory system	1,825	80.802	2.057	2.503	1.018	0.199
Brain and spinal cord	487	74.331	11.750	1.610	1.500	0.348
Digestive and excretory system (partial)	10,290	76.022	9.813	2.111	0.867	0.151
Offal fat	3,452	21.182	76.453	0.544	0.272	0.055
Heart and neck sweetbreads	481	69.816	14.598	2.329	1.655	0.405
Liver	1,978	70.479	1.914	2.958	1.402	0.315
Gall	122	90.916	0.078	0.224	1.038	0.070
Spleen	331	78.439	1.530	2.877	1.409	0.272
Pancreas	208	69.655	11.646	2.566	1.465	0.353
Kidneys	487	73.220	11.270	2.305	1.075	0.209
Hair and hide	15.342	64.339	1.342	5.564	1.063	0.063
Head and tail, lean and fat	1,496	66.304	15.440	2.701	0.893	0.148
Shin and shank, lean and fat	4,190	71.811	5.773	3.294	1.002	0.179
Flank and plate, lean and fat	11.036	57.700	23.466	2.774	0.852	0.160
Rump, lean and fat	2,096	59.745	21.117	2.669	0.892	0.154
Chuck and neck, lean and fat	22,284	68.487	11.963	2.971	0.931	0.174
Round, lean	16,324	75.971	2.699	3.159	1.093	0.202
Round, fat	1,702	30.528	58.733	1.707	0.449	0.068
Loin, lean	12,732	73.141	5.617	3.117	1.055	0.203
Loin. fat	2,360	19.936	72.602	0.977	0.293	0.054
Rib. lean	5,196	70.881	8.150	3.075	1.017	0.191
Rib, fat	426	30.179	56.423	1.454	0.725	0.114
Kidney, fat	622	6.747	90.964	0.340	0.176	0.034
Skeleton of feet	3.166	42.658	15.526	3.293	18.615	3.342
Skeleton of head	4,001	49.779	7.792	2.917	21.579	4.089
Skeleton of tail	135	52.455	14.133	3.189	11.275	1.944
Skeleton of shin	2.208	28.636	23.827	2.827	25.111	3.924
Skeleton of shank	2,608	30.367	22.437	3.389	23.653	3.670
Skeleton of flank and plate	2,144	49.188	14.542	3.198	15.045	2.447
Skeleton of rump	732	34.282	23.745	3.050	22.231	3.797
Skeleton of chuck and neck	5.412	38.139	16.952	3.337	23.969	3.555
Skeleton of round	2.556	29.961	32.225	2.423	20.600	3.177
Skeleton of loin	2.696	34.968	23.196	2.940	21.259	4.163
Skeleton of rib	2,154	36.366	16.613	3.179	22.619	4.031
Horns	250	54.908	0.529	5.783	9.976	1.895
Hoofs and dewclaws	635	66.631*	0.465	5.359	1.015	0.067
Teeth	240	28.678†	1.111	1.961	54.175	10.200

*Hoofs and dewclaws of steer 540 and steer 538 were analyzed together.
†Teeth of steer 540 and steer 538 were analyzed together.

TABLE 20.—STEER 540. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	6,967	82.280	1.030	2.806	0.724	0.026
Circulatory system	1,436	58.131	27.726	2.039	0.676	0.127
Respiratory system	1.501	79.609	2.314	2.592	1.032	0.198
Brain and spinal cord	512	73.656	11.940	1.617	1.579	0.375
Digestive and excretory system (partial)	9,280	75.239	10.756	1.995	1.703	0.129
Offal fat	2,307	25.244	71.058	0.548	0.282	0.047
Heart and neck sweetbreads	408	68.793	15.449	2.258	1.510	0.373
Liver	1,593	70.592	1.760	2.840	1.411	0.305
Gall	58	93.842	0.076	0.168	1.224	0.040
Spleen	331	77.793	1.372	3.097	1.408	0.271
Pancreas	180	72.201	9.605	2.537	1.457	0.343
Kidneys	363	72.153	10.499	2.368	1.084	0.223
Hair and hide	12,994	64.642	2.353	5.127	1.256	0.067
Head and tail, lean and fat	1,274	67.992	13.404	2.736	0.883	0.167
Shin and shank, lean and fat	3,762	74.264	4.038	3.397	1.039	0.185
Flank and plate, lean and fat	8.824	60.923	18.461	3.021	0.883	0.158
Rump, lean and fat	1,964	61.046	19.592	2.755	0.920	0.166
Chuck and neck, lean and fat	17,978	71.108	8.347	2.961	0.986	0.178
Round, lean	13.456	75.698	2.255	3.208	1.082	0.210
Round, fat	810	27.830	62.313	1.356	0.388	0.060
Loin, lean	10,700	73.545	4.187	3.179	1.075	0.201
Loin, fat	2.308	19.598	73.692	0.958	0.288	0.058
Rib, lean and fat	5,046	69.429	9.677	3.096	1.013	0.181
Kidney, fat	682	13.401	79.809	1.156	0.185	0.035

TABLE 20.—STEER 540. ANALYSIS OF SAMPLES—Continued.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Skeleton of feet	2,784	44.008	12.128	3.288	20.841	3.573
Skeleton of head	3,682	51.688	7.055	2.754	21.417	4.056
Skeleton of tail	138	55.385	12.477	2.254	10.059	1.771
Skeleton of shin	1,952	31.687	22.158	3.498	24.179	4.561
Skeleton of shank	2,304	33.134	24.266	2.969	21.100	3.760
Skeleton of flank and plate	1,862	53.192	12.085	3.378	12.087	2.902
Skeleton of rump	622	35.209	20.449	3.031	22.451	4.221
Skeleton of chuck and neck	4.896	41.285	14.741	3.264	19.664	3.532
Skeleton of round	2,350	35.287	27.370	2.523	16.708	2.801
Skeleton of loin	2,550	34.808	27.381	2.786	19.208	3.575
Skeleton of rib	1,824	34.170	18.773	3.297	22.860	4.637
Horns	304	54.266	0.593	5.453	12.472	2.411
Hoofs and dewclaws	635	66.631*	0.465	5.359	1.015	0.067
Teeth	278	28.678†	1.111	1.961	54.175	10.200

*Hoofs and dewclaws of steer 538 and steer 540 were analyzed together.
†Teeth of steer 538 and steer 540 were analyzed together.

TABLE 21.—STEER 541. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	12,470	82.112	0.089	2.773	0.679	0.027
Circulatory system	2,646	48.463	39.878	1.648	0.572	0.105
Respiratory system	2,387	79.217	1.976	2.738	1.040	0.213
Brain and spinal cord	568	72.458	13.605	1.658	1.525	0.371
Digestive and excretory system (partial)	16.313	71.285	14.700	2.024	0.746	0.134
Offal fat	11,009	11.714	86.398	0.293	0.125	0.026
Heart and neck sweetbreads	740	65.439	19.148	2.280	1.457	0.367
Liver	3,832	69.540	2.502	3.158	1.441	0.349
Gall	202	89.007	0.174	0.286	1.207	0.060
Spleen	596	77.687	1.811	2.876	1.326	0.279
Pancreas	390	59.915	23.448	2.036	1.192	0.285
Kidneys	645	73.472	9.902	2.223	1.076	0.214
Hair and hide	26,574	60.425	3.650	5.692	1.100	0.055
Head and tail, lean and fat	2,062	66.470	14.520	2.939	1.016	0.164
Shin and shank, lean and fat	6,830	68.724	9.020	2.923	0.956	0.178
Flank and plate, lean and fat	24,910	49.802	34.241	2.427	0.717	0.127
Rump, lean and fat	4,454	50.532	32.775	2.370	0.713	0.137
Chuck and neck, lean and fat	40,480	65.263	14.772	2.942	0.913	0.165
Round, lean	27,000	73.915	3.366	3.340	1.089	0.208
Round, fat	3,854	21.202	73.399	0.987	0.282	0.046
Loin, lean	23,416	71.952	5.559	3.233	1.050	0.198
Loin, fat	8.088	14.861	80.634	0.780	0.204	0.039
Rib, lean	11,588	68.657	10.433	3.126	0.796	0.187
Rib, fat	2,434	17.784	76.039	1.080	0.312	0.059
Kidney, fat	6,056	4.494	94.350	0.202	0.086	0.020
Skeleton of feet	4,506	41.552	12.840	3.435	21.608	3.743
Skeleton of head	5,400	50.560	7.061	2.995	20.107	3.657
Skeleton of tail	206	47.886	19.594	3.175	10.884	1.894
Skeleton of shin	2,946	28.889	23.422	3.102	27.138	3.798
Skeleton of shank	3,744	32.657	20.792	2.933	27.763	3.778
Skeleton of flank and plate	2,864	51.920	15.329	2.277	11.840	1.799
Skeleton of rump	1,056	30.290	24.456	3.061	25.444	4.853
Skeleton of chuck and neck	7,296	34.849	18.389	3.368	25.110	3.622
Skeleton of round	3,250	26.958	32.458	3.253	19.430	4.211
Skeleton of loin	3,916	34.343	24.734	3.216	20.081	3.905
Skeleton of rib	3,162	31.674	21.579	3.195	25.537	3.726
Horns	468	53.053	0.655	5.345	13.848	2.689
Hoofs and dewclaws	869	58.119	0.599	6.018	1.249	0.061
Teeth	304	46.836	0.937	1.458	40.727	7.826

TABLE 22.—STEER 547. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	8,711	80.850	....	2.942	0.717	0.029
Circulatory system	1,624	58.440	27.812	1.966	0.682	0.124
Respiratory system	1,868	78.906	2.817	2.547	1.149	0.195
Brain and spinal cord	459	77.158	8.963	1.537	1.460	0.367
Digestive and excretory system (partial)	11,978	74.163	10.929	2.138	1.042	0.192
Offal fat	3,879	18.056	78.881	0.660	0.257	0.053
Liver	2,851	71.964	2.581	2.956	1.364	0.366
Spleen	391	77.086	2.212	3.020	1.345	0.299
Pancreas	200	71.405	10.115	2.426	1.455	0.376
Kidneys	450	73.255	8.553	2.560	1.144	0.240
Hair and hide	14,618	64.546	1.829	5.330	1.295	0.072
Head, tail, shin and shank, lean and fat	8,590	68.763	12.261	2.818	0.897	0.173
Flank and plate, lean and fat	14,226	55.003	27.523	2.502	0.793	0.147
Rump, lean and fat	2.256	54.409	27.572	2.464	0.818	0.157
Chuck and neck, lean and fat	23,636	67.588	12.501	2.772	0.918	0.167
Round, lean	17.092	74.440	3.584	3.223	1.079	0.210
Round, fat	2,150	29.872	60.663	1.343	0.397	0.068
Loin, lean	13,576	71.512	6.124	3.182	1.030	0.199
Loin, fat	3,972	21.083	72.247	0.987	0.300	0.057
Rib, lean	6.560	69.801	9.433	3.043	0.979	0.180
Rib, fat	1.102	25.085	66.287	1.438	0.503	0.075
Kidney, fat	1,630	7.887	90.103	0.312	0.136	0.015
Skeleton of feet, head, tail, shin and shank	11,996	44.993	14.086	3.341	18.989	3.501
Skeleton of flank and plate	1,958	53.339	13.420	3.110	11.771	2.168
Skeleton of rump	760	37.716	15.923	3.294	23.682	4.444
Skeleton of chuck and neck	5,120	43.990	13.982	3.220	20.226	3.645
Skeleton of round	2,488	36.276	28.609	2.525	17.314	3.258
Skeleton of loin	3.132	39.384	20.100	2.909	20.155	3.841
Skeleton of rib	2,172	41.532	16.945	3.321	19.474	3.632
Horns, hoofs and dewclaws	737	53.209	1.331	7.310	2.465	0.220
Teeth	310	32.500	0.680	2.200	51.200	9.550

TABLE 23.—STEER 548. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	4,603	81.198	....	3.100	0.715	0.021
Circulatory system	753	70.180	12.580	2.606	0.843	0.157
Respiratory system	1,084	76.883	3.131	2.908	1.106	0.202
Brain and spinal cord	526	74.634	11.062	1.637	1.434	0.350
Digestive and excretory system, partial	5,357	78.972	4.268	2.386	1.066	0.179
Offal fat	845	52.573	36.778	1.461	0.720	0.122
Heart and neck sweetbreads	168	77.090	6.097	2.816	1.577	0.392
Liver	1,104	70.817	1.835	3.286	1.381	0.336
Spleen	215	77.264	1.368	3.131	1.342	0.281
Pancreas	85	75.456	6.206	2.812	1.394	0.331
Kidneys	353	78.549	3.384	2.489	1.237	0.247
Hair and hide	8,358	65.408	0.933	5.346	1.349	0.078
Head and tail, lean and fat	967	71.688	8.999	2.675	0.953	0.175
Shin and shank, lean and fat	2,462	74.845	4.448	3.267	0.998	0.175
Flank and plate, lean and fat	4,802	70.383	7.627	3.320	0.968	0.174
Rump, lean and fat	1,402	72.577	5.800	3.353	1.106	0.204
Chuck and neck, lean and fat	11,136	75.625	3.506	3.100	1.053	0.187
Round, lean	9,208	75.514	1.680	3.363	1.118	0.214
Round, fat	520	53.819	28.733	2.739	0.692	0.086
Loin, lean	5,668	75.325	2.020	3.292	1.128	0.209
Loin, fat	384	40.939	45.571	1.971	0.586	0.097
Rib, lean and fat	3,180	75.848	2.738	3.133	1.093	0.195
Kidney, fat	284	27.638	64.220	1.384	0.490	0.060
Skeleton of feet	2,496	45.620	13.826	3.344	18.414	3.215
Skeleton of head	2,989	56.949	6 785	2.771	17.108	3.133
Skeleton of tail	94	56.745	10.923	3.378	10.652	1.934
Skeleton of shin	1,584	38.976	19.708	3.222	19.487	3.568
Skeleton of shank	1,712	35.963	21.195	3.613	18.669	3.466
Skeleton of flank and plate	1,514	57.844	10.775	3.196	8.981	1.546
Skeleton of rump	570	43.892	15.924	3.252	18.272	3.323
Skeleton of chuck and neck	3.630	47.340	13.202	3.109	17.177	3.208
Skeleton of round	1.898	40.419	26.174	2.620	16.404	3.017
Skeleton of loin	1,652	43 992	18.943	3.128	17.030	3.230
Skeleton of rib	1,614	46 672	14.692	3.420	16.464	3.005
Horns, hoofs and dewclaws	435	55.591	1.144	6.927	2.606	0.264
Teeth	264	42.122	0.624	2.907	42.160	7.937

TABLE 24.—STEER 550. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	7,080	81.361	....	2.867	0.608	0.031
Circulatory system	1,163	55.997	29.913	1.989	0.660	0.133
Respiratory system	1,460	77.875	3.987	2.478	0.997	0.199
Brain and spinal cord	443	75.197	10.097	1.581	1.440	0.351
Digestive and excretory system (partial)	9,156	72.665	13.019	1.955	1.176	0.185
Offal fat	2.610	20.877	74.687	0.587	0.323	0.079
Liver	1,992	70.203	3.137	2.994	1.324	0.312
Spleen	291	76.774	2.659	2.941	1.480	0.325
Pancreas	200	66.906	15.542	2.442	1.338	0.320
Kidneys	379	75.357	6.259	2.503	1.173	0.252
Hair and hide	10,440	64.935	1.217	5.320	1.307	0.084
Head, tail, shin and shank, lean and fat	5,274	71.146	9.321	2.828	0.946	0.174
Flank and plate, lean and fat	7,896	61.653	19.406	2.857	0.888	0.164
Rump, lean and fat	1,662	59.888	20.746	2.688	0.918	0.178
Chuck and neck, lean and fat	15,814	67.239	14.099	2.685	0.950	0.180
Round, lean	11,720	75.505	2.653	3.418	1.063	0.213
Round, fat	944	32.441	57.921	1.439	0.416	0.069
Loin, lean	9.072	73.955	4.503	3.097	1.059	0.231
Loin, fat	2,134	21.819	71.450	0.918	0.326	0.065
Rib, lean and fat	4,408	69.082	11.035	2.924	0.996	0.187
Kidney, fat	756	10.430	86.878	0.455	0.229	0.057
Skeleton of feet, head, tail, shin and shank	9,839	45.940	15.646	2.949	18.669	3.461
Skeleton of flank and plate	1,540	52.599	12.791	3.242	12.161	2.167
Skeleton of rump	700	40.804	16.240	3.381	19.007	3.635
Skeleton of chuck and neck	4,956	44.877	16.362	3.097	18.062	3.294
Skeleton of round	2,100	36.994	28.692	2.629	16.908	3.207
Skeleton of loin	2,464	38.480	24.756	2.896	17.775	3.340
Skeleton of rib	1,740	41.987	17.627	3.296	18.509	3.404
Horns, hoofs and dewclaws	549	53.209	1.331	7.310	2.465	0.220
Teeth	228	32.500	0.680	2.200	51.200	9.550

TABLE 25.—STEER 552. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	5,219	79.774	....	3.010	0.854	0.028
Circulatory system	1,056	64.067	20.784	2.167	0.788	0.130
Respiratory system	1,096	77.900	2.614	2.724	1.206	0.205
Brain and spinal cord	466	74.074	11.478	1.564	1.369	0.335
Digestive and excretory system (partial)	5,936	75.009	9.539	2.159	1.058	0.174
Offal fat	1,784	28.924	67.756	0.924	0.380	0.069
Heart and neck sweetbreads	265	62.652	23.511	2.325	1.439	0.358
Liver	1,181	69.513	2.065	3.127	1.333	0.337
Spleen	284	77.867	1.297	3.100	1.340	0.279
Pancreas	101	73.221	9.258	2.422	1.292	0.301
Kidneys	316	72.871	12.099	2.305	1.128	0.221
Hair and hide	10,532	66.823	1.534	4.828	1.405	0.070
Head and tail, lean and fat	1,209	68.009	14.483	2.476	0.932	0.155
Shin and shank, lean and fat	2,976	74.470	4.636	3.211	0.976	0.172
Flank and plate, lean and fat	6,204	63.328	17.537	2.866	0.882	0.145
Rump, lean and fat	1,326	65.584	14.803	2.886	0.976	0.175
Chuck and neck, lean and fat	12,684	72.915	7.088	2.995	0.994	0.178
Round, lean	9,830	76.090	1.957	3.255	1.129	0.207
Round, fat	908	44.576	41.667	2.111	0.589	0.067
Loin, lean	7,034	74.559	3.588	3.131	1.101	0.194
Loin, fat	1,042	22.439	70.990	1.179	0.395	0.061
Rib, lean and fat	4,104	72.405	6.435	3.233	0.969	0.180
Kidney, fat	500	12.924	84.558	0.535	0.281	0.034
Skeleton of feet	2,861	43.452	12.823	3.478	19.568	3.480
Skeleton of head	3,052	54.140	6.234	2.916	18.811	3.453
Skeleton of tail	131	53.865	13.364	2.887	12.790	2.320
Skeleton of shin	1,550	39.817	17.664	3.553	18.794	3.332
Skeleton of shank	1,742	32.535	20.841	3.086	24.917	4.583
Skeleton of flank and plate	1,516	54.273	12.715	3.371	10.652	1.911
Skeleton of rump	640	39.791	17.248	3.300	20.750	3.671
Skeleton of chuck and neck	3,908	44.753	15.051	3.224	18.379	3.344
Skeleton of round	1.626	33.311	29.673	2.565	19.808	3.484
Skeleton of loin	2.192	41.054	20.912	2.874	18.374	3.457
Skeleton of rib	2.084	43.800	16.187	3.281	17.515	3.306
Horns, hoofs and dewclaws	550	57.684	1.828	6.410	2.692	0.261
Teeth	278	40.922	0.772	2.035	43.221	8.211

Table 26.—Steer 554. Analysis of Samples.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	4,197	81.073	....	2.890	0.801	0.031
Circulatory system	591	72.575	10.404	2.535	0.908	0.169
Respiratory system	907	79.018	2.438	2.691	1.209	0.227
Brain and spinal cord	395	76.826	8.780	1.774	1.581	0.350
Digestive and excretory system (partial)	4,216	77.716	7.707	2.132	1.098	0.189
Offal fat	644	41.234	50.872	1.202	0.634	0.099
Heart and neck sweetbreads	336	80.688	2.135	2.651	2.125	0.474
Liver	1,166	70.740	2.587	2.813	1.688	0.343
Spleen	202	78.308	1.436	2.961	1.484	0.312
Pancreas	76	70.340	13.270	2.357	1.501	0.280
Kidneys	530	81.509	2.392	2.221	1.152	0.215
Hair and hide	7,400	66.018	1.615	4.976	1.442	0.096
Head and tail, lean and fat	883	72.777	8.344	2.812	1.253	0.191
Shin and shank, lean and fat	2,304	74.453	3.945	3.321	1.126	0.176
Flank and plate, lean and fat	4,232	70.739	8.896	2.995	0.980	0.170
Rump, lean and fat	1,052	70.442	9.091	3.057	1.166	0.178
Chuck and neck, lean and fat	10,530	74.853	4.416	3.102	1.245	0.189
Round, lean	7,918	75.950	2.163	3.286	1.271	0.215
Round, fat	520	51.440	32.679	2.668	0.762	0.083
Loin, lean	5,812	74.847	3.700	3.199	1.150	0.207
Loin, fat	428	29.732	57.870	1.394	0.536	0.079
Rib, lean and fat	2,914	74.793	3.459	3.261	1.138	0.198
Kidney, fat	240	18.564	75.417	0.727	0.344	0.057
Skeleton of feet	2,403	46.494	13.980	3.702	17.687	3.284
Skeleton of head	2.229	59.707	3.158	3.111	16.850	3.152
Skeleton of tail	125	56.788	11.330	3.423	11.074	2.065
Skeleton of shin	1.464	40.004	18.416	3.221	20.982	3.982
Skeleton of shank	1,918	40.266	19.360	3.248	17.454	3.124
Skeleton of flank and plate	1.278	60.681	9.953	3.288	7.753	1.374
Skeleton of rump	732	48.799	12.664	3.475	16.288	2.950
Skeleton of chuck and neck	3,732	51.461	10.035	3.153	16.389	2.945
Skeleton of round	1,702	40.198	24.701	2.669	15.953	2.707
Skeleton of loin	1.868	50.157	13.850	2.994	14.999	2.690
Skeleton of rib	1,354	50.983	12.314	3.175	15.340	2.660
Horns, hoofs and dewclaws	338	55.271	1.451	7.670	2.390	0.229
Teeth	225	46.326	0.098	2.946	38.711	6.360

Table 27.—Steer 555. Analysis of Samples.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	4,529	80.075	....	3.124	0.738	0.035
Circulatory system	554	70.982	12.062	2.574	0.875	0.159
Respiratory system	937	79.445	2.779	2.693	1.115	0.208
Brain and spinal cord	353	76.371	9.945	1.705	1.535	0.354
Digestive and excretory system (partial)	4,534	78.376	6.357	2.319	1.091	0.189
Offal fat	462	58.692	31.373	1.720	0.779	0.119
Heart and neck sweetbreads	159	75.984	6.375	2.732	1.347	0.274
Liver	1,240	74.635	2.536	2.933	1.493	0.349
Spleen	167	77.376	1.363	3.129	1.308	0.276
Pancreas	106	76.261	5.510	2.622	1.458	0.293
Kidneys	439	81.997	2.743	2.220	1.181	0.223
Hair and hide	6,580	69.051	0.755	5.200	1.476	0.089
Head and tail, lean and fat	956	72.679	9.234	2.630	1.055	0.162
Shin and shank, lean and fat	2,688	77.046	2.331	3.187	1.044	0.181
Flank and plate, lean and fat	4,068	75.514	3.424	3.179	1.038	0.175
Rump, lean and fat	876	71.979	7.274	2.915	1.070	0.187
Chuck and neck, lean and fat	9,402	77.450	2.143	3.130	1.041	0.185
Round, lean	7,126	77.949	1.347	3.059	1.194	0.207
Round. fat	376	58.987	23.814	2.599	0.747	0.090
Loin, lean	4,618	77.939	1.726	3.105	1.200	0.208
Loin. fat	274	44.153	42.967	2.179	0.822	0.100
Rib, lean and fat	2,512	77.614	2.536	3.101	1.174	0.189
Kidney, fat	130	32.970	57.414	1.209	0.549	0.091
Skeleton of feet	2,157	51.458	9.040	4.041	16.248	2.781
Skeleton of head	1,978	62.439	3.214	2.859	14.812	2.570
Skeleton of tail	74	63.368	6.593	3.646	9.138	1.523
Skeleton of shin	1,454	50.339	11.063	3.234	17.828	3.190
Skeleton of shank	1,704	49.701	13.806	2.882	14.863	2.656

TABLE 27.—STEER 555. ANALYSIS OF SAMPLES—Continued.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Skeleton of flank and plate	1,236	65.173	5.690	3.369	8.036	1.361
Skeleton of rump	506	57.102	5.911	3.496	16.138	2.764
Skeleton of chuck and neck	3,216	59.309	5.153	3.142	13.912	2.463
Skeleton of round	1,652	53.566	13.254	2.793	14.801	2.582
Skeleton of loin	1,264	59.306	7.164	3.098	13.007	2.313
Skeleton of rib	1,256	58.491	6.345	3.269	13.194	2.272
Horns, hoofs and dewclaws	298	48.852	0.914	7.593	2.662	0.133
Teeth	190	42.647	0.330	2.870	42.862	7.297

TABLE 28.—STEER 556. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	6,124	81.472	....	2.778	0.784	0.035
Circulatory system	993	62.355	23.955	2.146	0.856	0.148
Respiratory system	1,272	77.682	3.420	2.698	1.400	0.216
Brain and spinal cord	398	67.120	19.452	1.624	1.616	0.349
Digestive and excretory system (partial)	6,003	74.523	10.512	2.203	1.304	0.241
Offal fat	1,402	32.618	61.309	0.961	0.451	0.063
Heart and neck sweetbreads	328	76.405	6.578	2.590	2.052	0.452
Liver	1,760	71.112	3.500	3.060	2.295	0.366
Spleen	300	77.717	2.323	2.983	1.480	0.272
Pancreas	96	72.244	10.649	2.415	1.503	0.302
Kidneys	338	75.331	7.087	2.522	1.345	0.254
Hair and hide	10,314	66.284	2.153	5.157	1.377	0.088
Head and tail, lean and fat	914	68.746	13.192	2.739	0.897	0.165
Shin and shank, lean and fat	2,808	73.731	4.508	3.271	0.966	0.185
Flank and plate, lean and fat	6,174	67.267	13.359	3.143	0.935	0.168
Rump, lean and fat	1,244	69.336	10.388	3.015	1.036	0.191
Chuck and neck, lean and fat	12,406	72.316	7.615	3.016	1.246	0.180
Round, lean	9,472	75.179	3.195	3.289	1.251	0.210
Round, fat	686	44.562	43.541	2.194	0.577	0.069
Loin, lean	6,938	74.185	3.780	3.270	1.189	0.206
Loin, fat	820	26.114	66.035	1.399	0.542	0.064
Rib, lean and fat	3,300	71.440	7.223	3.184	1.153	0.184
Kidney, fat	420	15.362	80.619	0.587	0.355	0.037
Skeleton of feet	2,589	46.442	14.176	3.729	17.758	3.279
Skeleton of head	2,610	56.628	7.187	2.990	17.629	3.271
Skeleton of tail	92	56.900	9.965	3.538	13.365	2.393
Skeleton of shin	1,702	40.276	19.800	3.280	19.776	3.695
Skeleton of shank	1,952	37.454	22.610	3.389	19.971	3.787
Skeleton of flank and plate	1,578	57.659	11.660	3.313	10.266	1.862
Skeleton of rump	608	47.189	13.166	3.537	18.150	3.408
Skeleton of chuck and neck	3,734	47.104	12.535	3.488	18.545	3.545
Skeleton of round	1,974	38.147	25.725	2.665	16.702	3.212
Skeleton of loin	2,268	46.157	15.957	3.158	16.929	3.309
Skeleton of rib	1,646	46.368	12.349	3.310	18.157	3.720
Horns, hoofs and dewclaws	390	48.189	1.236	8.303	1.870	0.156
Teeth	218	41.753	0.042	2.938	43.927	6.910

TABLE 29.—STEER 557. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	8,952	79.941	....	3.136	0.842	0.027
Circulatory system	2,342	50.516	38.557	1.650	0.615	0.105
Respiratory system	1,972	77.053	5.258	2.598	1.119	0.203
Brain and spinal cord	551	72.578	12.435	1.790	1.410	0.338
Digestive and excretory system (partial)	9,981	73.851	11.446	2.007	1.051	0.176
Offal fat	6,757	13.945	83.471	0.435	0.229	0.029
Heart and neck sweetbreads	623	67.787	16.888	2.328	1.653	0.357
Liver	3,003	69.463	1.882	3.084	1.344	0.332
Spleen	485	76.934	3.341	2.888	1.372	0.281
Pancreas	225	64.844	17.153	2.276	1.068	0.251
Kidneys	649	76.753	5.885	2.376	1.151	0.218
Hair and hide	14,100	63.124	5.012	4.988	1.171	0.071
Head and tail, lean and fat	1,915	60.473	21.133	2.352	0.848	0.144
Shin and shank, lean and fat	4,196	68.205	11.827	2.933	0.927	0.153
Flank and plate, lean and fat	15,294	50.434	34.335	2.334	0.778	0.133
Rump, lean and fat	2,582	51.177	32.845	2.317	0.797	0.142
Chuck and neck, lean and fat	22,146	63.903	17.574	2.702	0.957	0.183
Round, lean	14,960	73.824	4.610	3.073	1.011	0.194
Round, fat	2,532	27.746	63.644	1.019	0.349	0.048
Loin, lean	11,714	71.155	7.826	2.966	1.098	0.192
Loin, fat	4,472	15.907	79.899	0.729	0.248	0.038
Rib, lean	6,372	67.831	11.987	2.905	0.958	0.170
Rib, fat	1,616	19.571	73.914	0.959	0.360	0.059
Kidney, fat	3,228	8.267	89.768	0.367	0.159	0.024
Skeleton of feet	3,558	44.384	11.995	3.601	18.856	3.488
Skeleton of head	3,969	53.816	6.263	2.751	18.265	3.294
Skeleton of tail	193	53.009	16.791	3.163	10.458	1.954
Skeleton of shin	2,246	36.792	18.013	3.351	21.238	3.961
Skeleton of shank	2,610	36.883	19.539	3.405	20.052	3.625
Skeleton of flank and plate	2,498	56.391	12.656	3.152	9.709	1.721
Skeleton of rump	960	42.749	13.401	3.441	19.159	3.710
Skeleton of chuck and neck	5,638	42.943	12.074	3.394	20.847	3.764
Skeleton of round	2,686	32.505	29.395	2.573	19.164	3.548
Skeleton of loin	2,478	38.626	20.143	2.959	19.381	3.655
Skeleton of rib	2,572	40.350	16.831	3.239	19.671	3.611
Horns, hoofs and dewclaws	695	53.666	1.415	6.956	2.569	0.279
Teeth	261	39.979	0.283	2.874	46.115	8.632

TABLE 30.—STEER 558. ANALYSIS OF SAMPLES.

Description of sample	Weight in animal, grams	Moisture %	Crude fat %	Nitrogen %	Ash %	Phosphorus %
Blood	4,666	83.665	....	2.509	0.692	0.039
Circulatory system	971	66.245	19.036	2.219	0.726	0.143
Respiratory system	1,111	79.632	1.472	2.685	1.054	0.231
Brain and spinal cord	520	75.596	10.002	1.596	1.507	0.374
Digestive and excretory system (partial)	6,510	77.962	6.366	2.241	0.992	0.188
Offal fat	829	47.598	43.206	1.386	0.505	0.106
Liver	1,352	71.470	2.100	3.096	1.349	0.352
Spleen	193	75.805	1.099	3.298	1.537	0.278
Pancreas	153	76.282	5.186	2.553	1.452	0.374
Kidneys	318	76.794	4.347	2.595	1.193	0.247
Hair and hide	8,138	64.713	1.078	5.287	1.130	0.083
Head, tail, shin and shank, lean and fat	4,324	74.380	5.509	2.948	0.943	0.163
Flank and plate, lean and fat	4,192	70.650	7.311	3.229	0.923	0.172
Rump, lean and fat	1,030	69.840	9.636	3.089	1.011	0.196
Chuck and neck, lean and fat	11,682	75.244	4.121	3.041	0.927	0.187
Round, lean	9,664	77.152	1.113	3.116	1.049	0.213
Round, fat	644	44.994	41.335	2.308	0.611	0.095
Loin, lean	5,962	74.950	2.652	3.182	1.025	0.210
Loin, fat	600	30.204	59.420	1.549	0.446	0.080
Rib, lean and fat	3,242	74.678	3.490	3.157	0.990	0.197
Kidney, fat	220	18.408	75.158	0.936	0.283	0.055
Skeleton of feet, head, tail, shin and shank	9,785	45.737	16.814	3.097	17.541	3.252
Skeleton of flank and plate	1,092	54.633	12.549	3.306	10.416	1.885
Skeleton of rump	678	42.549	18.378	3.113	18.671	3.383
Skeleton of chuck and neck	4,056	43.212	18.090	3.089	17.848	3.240
Skeleton of round	2,094	34.269	33.809	2.285	16.162	2.982
Skeleton of loin	2,138	39.771	25.039	2.529	17.837	3.281
Skeleton of rib	1,516	46.885	16.047	3.348	15.188	2.747
Horns, hoofs and dewclaws	443	53.209	1.331	7.310	2.465	0.220
Teeth	274	32.500	0.680	2.200	51.200	9.550

TABLE 31.—STEER 500. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	21,269	16811.2	40.8	679.1	167.8	4.68
Circulatory system	1,562	756.8	587.9	29.2	8.5	0.95
Lean heart	1,284	995.7	45.7	35.0	14.2	2.67
Respiratory system	3,747	2866.5	101.2	106.4	42.9	6.45
Fat from thoracic cavity	568	96.8	450.9	2.8	1.4	0.14
Brain and spinal cord	832	522.2	180.7	13.9	14.5	3.09
Digestive and excretory system (partial)	19,275	14385.9	1921.9	424.6	160.8	22.75
Offal fat	12,940	1747.0	10812.2	54.6	23.8	2.59
Heart and neck sweetbreads	538	286.2	182.6	9.9	5.6	1.21
Liver	4,634	3233.9	134.5	150.3	73.2	14.97
Gall	241	221.4	0.5	0.5	3.0	0.07
Spleen	1,054	783.9	56.4	31.4	12.6	2.31
Pancreas	625	369.6	156.8	13.4	7.5	1.60
Kidneys	1,019	785.6	49.0	24.7	11.4	2.11
Tongue, marketable	1,619	1123.7	192.2	43.8	14.8	2.49
Hair and hide	35,938	21320.9	474.0	2256.9	385.3	15.81
Head and tail, lean and fat	3,784	2410.9	603.9	119.4	33.4	5.07
Shin and shank, lean and fat	12,496	8854.9	823.6	420.2	123.6	20.49
Flank and plate, lean and fat	36,410	19948.3	10067.7	978.3	315.3	50.61
Rump, lean and fat	7,058	3892.4	1950.8	178.4	57.8	10.23
Chuck and neck, lean and fat	58,918	39825.0	6993.0	1995.6	537.3	93.09
Round, lean	39,898	29536.9	1390.5	1246.0	403.4	76.21
Round, fat	4,936	1370.6	3032.8	78.5	18.6	2.52
Loin, lean	29,692	20864.3	2296.4	924.3	299.9	54.93
Loin, fat	6,830	1124.5	5225.5	40.8	16.7	2.60
Rib, lean	13,602	9132.0	1676.2	434.7	126.4	23.12
Rib, fat	1,804	367.4	1282.4	23.3	6.7	1.08
Kidney, fat	2,432	170.9	2195.5	10.0	3.5	0.44
Skeleton of feet	6,838	2708.1	788.3	247.0	1707.5	309.69
Skeleton of head	8,953	4296.2	1216.2	312.2	1599.2	307.45
Skeleton of tail	386	151.7	92.7	10.2	61.4	10.75
Skeleton of shin	5,610	1485.9	1210.9	207.6	1651.6	292.34
Skeleton of shank	5,750	1808.8	1160.8	198.6	1448.0	254.67
Skeleton of flank and plate	6,350	2605.5	1143.5	204.7	1177.1	203.20
Skeleton of rump	2,988	727.3	914.6	91.6	749.8	132.37
Skeleton of chuck and neck	14,450	4302.5	3253.7	442.2	3746.3	661.09
Skeleton of round, (excl. marrow)	6,438	2095.7	1789.3	166.7	1356.7	243.74
Marrow from skeleton of round	680	64.3	606.9	1.0	1.5	0.21
Skeleton of loin	7,772	1947.4	2438.5	228.1	1865.8	332.41
Skeleton of rib	5,192	1409.4	1158.2	165.2	1449.9	257.11
Hoofs and dewclaws	2 095	1059.7	17.5	162.2	54.6	2.45
Teeth	852	181.7	9.9	17.7	519.8	98.12

TABLE 32.—STEER 501. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	28,710	22387.2	50.5	944.6	246.0	7.18
Circulatory system	1,836	770.4	842.5	35.0	8.7	0.90
Lean heart	1,882	1460.7	70.4	48.4	18.7	3.73
Respiratory system	3,838	2939.0	128.5	110.3	40.0	6.60
Fat from thoracic cavity	2,459	463.1	1884.7	15.1	5.8	0.64
Brain and spinal cord	757	533.0	100.5	12.7	13.9	2.97
Digestive and excretory system (partial)	24,235	17390.1	3119.0	519.4	196.1	29.81
Offal fat	38,625	2892.2	35172.3	79.2	39.4	4.64
Heart and neck sweetbreads	784	241.1	484.2	7.8	3.9	0.84
Liver	6,161	4282.7	178.6	199.2	87.7	20.58
Gall	176	161.8	0.1	0.4	2.2	0.06
Spleen	1,178	917.6	23.0	32.7	16.3	2.82
Pancreas	836	500.5	205.4	18.4	9.6	2.20
Kidneys	1,037	805.3	50.5	24.3	10.9	2.06
Tongue, marketable	2,153	1417.6	348.8	56.2	18.7	3.38
Hair and hide	50,090	25762.3	6629.4	2751.4	762.4	24.54
Head and tail, lean and fat	5,224	3156.4	1083.8	148.0	40.1	6.58
Shin and shank, lean and fat	17,420	10268.9	3932.2	471.6	134.5	23.17
Flank and plate, lean and fat	134,146	35964.5	88380.8	1408.5	458.8	76.46
Rump, lean and fat	22,226	6394.2	13949.0	253.4	87.8	15.33
Chuck and neck, lean and fat	110,990	52940.0	42652.4	1692.6	723.7	130.97
Round, lean	50,130	35041.9	4690.2	1549.0	479.7	92.74
Round, fat	22,284	3754.0	17434.3	148.6	48.6	5.79
Loin, lean	45,996	28773.7	8248.9	1316.9	391.4	74.97
Loin, fat	71,358	6444.3	63281.7	276.9	79.9	12.84
Rib, lean	20,834	12269.6	4668.7	574.8	164 8	31.04
Rib, fat	28,322	2746.4	24764.5	113.6	38.0	5.66
Kidney, fat	19,544	1067.5	18236.7	37.1	13.1	2.15
Skeleton of feet	7,744	2792.0	954.5	273.4	2023.7	390.68

TABLE 32.—STEER 501. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS—Cont.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Skeleton of head	10,462	4561.8	1232.0	343.9	2487.5	439.30
Skeleton of tail	394	124.3	58.3	10.6	54.9	9.59
Skeleton of shin	6,170	2018.3	875.4	214.5	1787.3	323.12
Skelcton of shank	7,128	1920.5	1581.5	238.7	1985.9	365.24
Skeleton of flank and plate	7,068	2842.3	1107.0	234.7	1328.9	240.52
Skeleton of rump	3,682	932.8	965.2	116.8	956.3	172.61
Skeleton of chuck and neck	15,778	4750.1	2444.8	576.8	4478.0	821.24
Skeleton of round, (excl. marrow)	6,978	1859.4	1699.2	215.3	1901.7	345.27
Marrow from skeleton of round	286	29.1	252.8	0.6	1.5	0.24
Skeleton of loin	8,614	2214.8	1940.1	269.4	2447.3	436.90
Skeleton of rib	6,388	1816.0	1173.5	212.2	1780.2	330.96
Horns	3,354	1240.6	21.2	217.0	762.8	139.76
Hoofs and dewclaws	2,523	1186.1	16.6	213.3	43.3	3.61
Teeth	778	172.0	6.3	16.1	465.1	91.31

TABLE 33.—STEER 502. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Asn	Phosphorus
Blood	19,728	15276.0	....	688.9	142.0	4.54
Circulatory system	3,446	2353.1	500.1	89.1	23.4	4.76
Respiratory system	3,696	2815.1	113.0	104.6	38.4	6.14
Fat from thoracic cavity	1,271	273.3	933.9	9.6	3.8	0.52
Brain and spinal cord	800	552.8	116.8	13.7	14.4	3.31
Digestive and excretory system (partial)	20,933	16122.6	1263.3	522.3	264.6	28.47
Offal fat	11,377	1211.8	9804.7	53.2	21.1	2.62
Heart and neck sweetbreads	502	300.1	127.6	11.3	5.8	1.36
Liver	3,716	2561.9	64.2	122.8	51.7	12.41
Gall	241	224.2	0.1	0.5	2.5	0.07
Spleen	921	711.9	22.3	26.1	16.9	2.57
Pancreas	581	310.6	172.1	12.6	6.2	1.39
Kidneys	838	617.3	55.2	22.5	9.3	1.85
Hair and hide	39,556	22665.2	1190.6	2600.4	386.1	23.34
Head and tail, lean and fat	4,250	2745.5	600.2	136.0	35.1	6.33
Shin and shank, lean and fat	12,364	8444.0	1072.1	431.0	109.3	20.28
Flank and plate, lean and fat	35,594	18475.1	11113.2	919.4	247.7	42.36
Rump, lean and fat	8,100	4538.3	2059.5	211.5	64.6	11.91
Chuck and neck, lean and fat	70,744	46926.6	9004.3	2173.3	651.6	111.78
Round, lean	44,426	32054.7	1799.7	1468.7	431.4	86.63
Round, fat	4,620	1229.0	2903.1	71.6	14.9	1.76
Loin, lean	35,104	24529.6	2852.5	1120.9	342.3	69.86
Loin, fat	9,144	1416.4	7149.0	95.7	22.8	3.29
Rib, lean	18,256	12114.3	1846.8	560.1	163.0	29.94
Rib, fat	3,338	689.5	2336.4	49.5	9.4	1.70
Kidney, fat	2,916	215.4	2614.7	12.3	7.0	1.14
Skeleton of feet	6,982	2697.3	852.2	264.5	1666.5	296.04
Skeleton of head	9,577	4669.5	802.4	305.0	1934.2	331.36
Skeleton of tail	441	178.3	99.6	14.3	66.5	12.05
Skeleton of shin	5,940	1627.5	1147.6	209.8	1750.3	311.97
Skeleton of shank	5,978	1625.8	1469.7	206.5	1516.2	269.31
Skeleton of flank and plate	5,590	2300.6	726.5	189.1	1219.6	215.83
Skeleton of rump	2,362	600.8	702.3	71.5	559.4	99.96
Skeleton of chuck and neck	15,092	4643.4	2755.7	514.2	4158.3	742.22
Skelcton of round (excl. marrow)	6,296	1667.0	1664.9	188.6	1653.3	294.72
Marrow from skeleton of round	408	32.1	369.8	0.8	1.7	0.30
Skelcton of loin	7,866	2068.0	2085.6	247.7	2032.5	359.40
Skeleton of rib	5,920	1801.6	1219.5	215.9	1472.0	260.54
Horns*	1,949	745.9	11.9	131.0	410.3	72.76
Hoofs and dewclaws	2,010	1179.6	11.5	133.2	23.8	2.41
Teeth	1,038	375.9	10.6	16.9	519.0	98.43

*This sample was lost before analysis. The average analysis of the horns of two mature steers in the same group was used.

TABLE 34.—STEER 503. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	13.058	10809.4	14.4	353.6	43.9	9.92
Circulatory system	1.782	645.9	978.6	22.3	5.9	1.07
Lean heart	1.063	830.6	39.7	27.5	10.1	2.20
Respiratory system	2,549	2006.2	80.4	67.7	24.9	5.28
Brain and spinal cord	666	486.9	107.3	11.2	10.3	2.62
Digestive and excretory system (partial)	8,761	6370.1	964.9	208.1	88.7	18.22
Offal fat	7,385	1081.3	6049.8	38.5	13.4	2.58
Liver	3,646	2504.1	192.0	109.2	46.8	12.18
Kidneys	655	467.4	77.3	15.8	6.8	1.47
Stomach	5,765	4477.0	399.2	127.5	62.6	11.93
Tongue, marketable	789	547.0	104.7	20.0	6.5	1.34
Hair and hide	23,008	15591.4	591.3	1102.8	225.3	15.18
Shin, shank, head and tail, lean and fat	8,614	6004.6	880.6	275.3	72.9	14.46
Flank and plate, lean and fat	16,290	9206.8	4181.0	446.7	121.9	22.17
Chuck and neck, lean and fat	31,934	21883.1	4015.4	943.3	278.0	54.61
Round and rump, lean	25,022	18287.8	1202.3	843.2	256.1	51.14
Round and rump, fat	3,400	763.3	2384.4	41.2	9.8	1.62
Loin, lean	17,206	12215.2	1454.1	548.4	169.1	32.69
Loin, fat	5,746	904.9	4592.0	44.7	10.9	2.01
Rib, lean	8,932	6223.6	913.8	281.7	82.8	16.52
Rib, fat	840	195.7	562.3	12.4	2.7	0.51
Kidney, fat	2,126	184.5	1902.1	7.2	2.7	0.58
Skeleton	41,122	15740.3	6192.6	1276.4	9747.6	1800.32
Horns, hoofs and dewclaws	1,058	489.7	21.5	80.2	64.1	6.99
Teeth	253	59.0	1.3	5.7	149.0	28.54

TABLE 35.—STEER 504. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	21,005	16520.4	19.5	700.3	81.3	4.62
Circulatory system	1,637	470.0	1043.3	18.2	6.6	0.67
Lean heart	1,428	1094.6	61.6	39.6	14.5	2.90
Respiratory system	3,628	2445.6	540.6	104.6	35.3	6.57
Brain and spinal cord	724	501.2	109.2	13.0	9.8	2.53
Digestive and excretory system (partial)	17,569	12041.8	3169.5	335.6	127.6	25.48
Offal fat	25,105	3203.4	21294.1	83.9	39.9	5.77
Liver	4,754	3280.7	115.8	155.7	64.3	17.02
Kidneys	877	609.3	112.3	21.5	9.3	1.92
Stomach	12,820	10213.7	1030.7	218.1	115.0	19.36
Tongue, marketable	1,587	964.1	372.6	34.6	12.1	2.24
Hair and hide	41,144	23982.8	3320.3	2272.0	434.9	17.69
Shin, shank, head and tail, lean and fat	16,070	9744.9	3304.0	474.2	129.0	23.46
Flank and plate, lean and fat	49,650	20674.3	22650.3	965.7	284.0	50.15
Rump, lean and fat	10,846	4416.5	5077.0	200.3	62.3	11.50
Chuck and neck, lean and fat	59,808	34886.0	14371.9	1567.0	453.3	87.32
Round, lean	37,238	25884.1	3429.6	1194.6	366.1	72.24
Round, fat	9,818	1630.8	7661.0	89.0	23.4	2.95
Loin, lean	33,676	22535.9	4115.2	1027.5	318.6	60.95
Loin, fat	18,340	2131.1	15572.5	97.6	29.7	4.59
Rib, lean	18,506	11710.6	3242.3	544.1	153.8	30.91
Rib, fat	6,770	976.2	5458.7	56.4	13.7	2.10
Kidney, fat	11,400	547.2	10709.2	24.5	14.4	1.94
Skeleton of feet, head, tail, shin and shank	23,568	8496.3	3214.7	762.9	6503.4	1196.31
Skeleton of flank and plate	4,572	2916.3	831.2	161.1	718.5	133.32
Skeleton of rump	2,428	624.5	631.3	74.6	664.8	125.87
Skeleton of chuck and neck	11,176	3372.9	1818.3	393.8	3259.2	597.25
Skeleton of round	4,808	1052.0	1320.8	150.0	1492.8	276.70
Skeleton of loin	5,850	1745.6	1292.9	186.3	1547.4	281.50
Skeleton of rib	5,092	1657.5	828.0	174.0	1415.1	259.49
Horns, hoofs and dewclaws	2,532	1759.1	13.0	117.0	61.5	3.98
Teeth*	338	86.2	3.6	6.4	196.8	37.57

*This sample was lost before analysis. The average analysis of the teeth of four steers of the same Group was used.

TABLE 36.—STEER 505. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	13,810	11360.1	48.5	376.5	45.4	3.18
Circulatory system	1,168	388.1	689.9	15.0	3.2	0.55
Lean heart	938	725.8	47.9	24.6	9.1	1.96
Respiratory system	2,498	1919.2	136.8	67.8	23.8	5.05
Brain and spinal cord	537	396.4	79.1	9.1	9.2	2.21
Digestive and excretory system (partial)	8,258	5936.9	1058.3	204.5	87.0	18.66
Offal fat	12,781	1586.1	10912.9	43.5	15.0	2.81
Liver	3,983	2712.3	229.8	127.7	52.9	13.82
Kidneys	718	543.6	56.3	17.1	7.6	1.62
Stomach	8,818	6812.9	956.7	148.2	76.5	15.26
Tongue, marketable	1,115	714.3	224.8	26.2	8.5	1.74
Hair and hide	22,884	14219.7	1221.1	1212.2	159.3	15.10
Shin, shank, head and tail, lean and fat	9,386	6047.4	1445.3	301.9	76.8	15.40
Flank and plate, lean and fat	24,194	10577.6	10345.8	535.0	140.3	28.07
Chuck and neck, lean and fat	38,344	23886.0	7265.8	1106.6	318.3	63.27
Round and rump, lean	25,784	17808.0	2440.2	857.6	251.7	51.57
Round and rump, fat	5,970	844.2	4814.2	27.0	10.4	1.91
Loin, lean	19,686	13423.9	1965.3	637.0	189.6	38.58
Loin, fat	7,558	705.4	6616.8	40.4	9.6	1.83
Rib, lean	11,300	6979.1	2168.6	334.9	95.0	19.89
Rib, fat	2,640	288.1	2254.2	17.0	4.4	0.87
Kidney, fat	5,754	302.8	5381.5	13.6	4.8	0.92
Skeleton	37,745	13509.7	6626.2	1202.6	9002.9	1661.92
Horns, hoofs and dewclaws	1,206	555.9	12.2	93.2	64.4	7.37
Teeth	268	58.8	1.7	6.1	159.2	28.67

TABLE 37.—STEER 507. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	20,316	15881.8	....	697.0	136.1	4.47
Circulatory system	4,278	2015.7	1765.7	72.5	22.9	4.45
Respiratory system	3,768	2919.0	148.0	108.8	35.9	6.37
Brain and spinal cord	744	526.8	102.2	11.2	13.0	3.11
Digestive and excretory system	27,417	19333.1	3860.0	574.9	226.2	41.13
Offal fat	11,307	1480.8	9493.6	46.6	15.8	3.28
Hair and hide	34,473	20975.1	2141.8	1960.8	367.1	16.89
Head and tail, lean and fat	4,038	2527.1	765.2	114.7	36.1	6.51
Shin and shank, lean and fat	11,860	8288.1	932.2	396.5	109.2	19.81
Flank and plate, lean and fat	36,130	18765.6	11692.4	904.7	250.4	44.81
Rump, lean and fat	7,736	3930.1	2448.0	176.0	55.8	10.75
Chuck and neck, lean and fat	62,530	41000.3	9483.3	1807.7	539.0	98.07
Round, lean	39,302	28583.2	2268.5	1269.5	385.6	75.46
Round, fat	5,378	1314.7	3693.1	58.8	14.8	2.10
Loin, lean	29,724	21013.7	2406.5	929.8	288.9	54.99
Loin, fat	10,188	1815.7	7812.6	84.2	22.7	3.97
Rib, lean	15,788	10647.1	1932.3	473.5	147.9	27.47
Rib, fat	2,432	426.9	1858.9	23.0	6.2	1.02
Kidney, fat	4,376	296.9	3995.3	12.4	6.4	1.09
Skeleton of feet, head and tail	15,275	6538.3	1798.8	527.9	3651.6	589.31
Skeleton of shin and shank	10,350	2479.9	2003.5	377.4	3489.7	479.62
Skeleton of flank and plate	6,278	2775.9	846.6	212.2	1159.7	178.99
Skeleton of rump	2,536	635.0	668.0	81.9	655.2	99.92
Skeleton of chuck and neck	13,202	4222.4	2012.6	469.3	3385.5	555.01
Skeleton of round	5,864	1530.1	1756.9	184.3	1360.7	244.00
Skeleton of loin	6,506	1732.6	1749.5	186.5	1698.2	242.28
Skeleton of rib	5,050	1448.0	910.1	169.8	1451.3	216.24
Horns	1,600	665.7	10.0	92.2	350.0	63.36
Hoofs and dewclaws	1,490	811.1	17.0	104.3	30.5	2.43
Teeth	712	188.9	7.3	14.0	403.8	77.53

TABLE 38.—STEER 509. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	18.291	14276.7	....	627.2	125.5	4.21
Circulatory system	2,616	1829.8	320.8	67.8	24.1	4.37
Respiratory system	3,283	2529.0	94.5	98.6	33.2	5.78
Fat from thoracic cavity	1,248	247.2	949.7	9.0	3.7	0.54
Brain and spinal cord	739	494.2	130.5	12.4	11.7	2.80
Digestive and excretory system (partial)	19.016	13883.8	2260.2	419.5	172.7	23.39
Offal fat	9,922	1127.1	8521.8	53.0	17.4	2.38
Heart and neck sweetbreads	630	316.9	234.0	11.4	6.6	1.60
Liver	3,875	2650.8	68.1	119.7	51.7	12.63
Gall	110	100.7	0.1	0.3	1.0	0.03
Spleen	1,304	1007.4	27.7	39.0	18.5	3.16
Pancreas	562	308.6	159.9	12.6	6.6	1.51
Kidneys	774	596.1	29.6	20.5	8.6	1.81
Hair and hide	37,614	22180.6	931.7	2358.4	385.2	17.30
Head and tail, lean and fat	3,212	2144.6	418.3	98.8	26.4	4.82
Shin and shank, lean and fat	11.782	8001.4	1150.5	398.2	107.3	19.68
Flank and plate, lean and fat	31.790	17051.8	9195.6	832.9	233.0	46.10
Rump, lean and fat	7.370	4113.4	1960.4	193.7	59.3	10.76
Chuck and neck, lean and fat	60.176	41216.4	5931.0	1851.0	538.6	99.89
Round, lean	40.376	29735.7	1688.9	1301.3	405.8	79.14
Round, fat	5,106	1305.0	3269.9	82.8	17.5	2.09
Loin, lean	30,836	21471.7	2778.3	956.8	293.3	55.50
Loin, fat	7,570	1230.8	5871.4	78.2	19.2	3.10
Rib, lean	16.360	11091.3	1774.1	478.9	149.7	27.81
Rib, fat	1,978	347.2	1503.7	20.9	5.5	0.89
Kidney, fat	1.576	86.1	1456.4	5.0	2.2	0.27
Skeleton of feet	6.144	2523.7	662.2	225.4	1441.2	260.81
Skeleton of head	8,247	3920.6	699.2	261.9	1745.4	311.08
Skeleton of tail	386	146.5	102.5	11.1	58.3	10.55
Skeleton of shin	5,046	1430.6	918.5	193.7	1480.5	260.78
Skeleton of shank	5.498	1569.7	1240.2	193.5	1437.4	276.38
Skeleton of flank and plate	5,124	2119.7	667.8	181.0	1146.9	209.16
Skeleton of rump	2,860	769.2	850.7	87.5	636.2	110.91
Skeleton of chuck and neck	13,682	4431.2	2366.0	506.8	3426.8	630.19
Skeleton of round (excl. marrow)	5,442	1521.4	1342.0	161.5	1412.1	251.64
Marrow from skeleton of round	578	67.4	502.0	1.2	2.1	0.34
Skeleton of loin	6,872	1891.0	1763.4	215.1	1762.5	303.33
Skeleton of rib	4,986	1398.6	837.2	180.6	1524.2	271.44
Hoofs and dewclaws	1,590	1065.0	7.3	82.6	23.2	1.86
Teeth	838	239.1	4.5	14.6	469.3	88.27

TABLE 39.—STEER 512. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	24,176	19328.5	13.3	742.9	191.0	5.56
Circulatory system	2,432	985.7	1167.0	41.6	13.7	1.34
Lean heart	1,555	1202.3	54.0	43.6	19.7	3.34
Respiratory system	3,881	2929.7	181.2	108.8	41.9	6.36
Fat from thoracic cavity	1,171	143.2	1001.5	3.1	1.7	0.18
Brain and spinal cord	666	479.9	74.0	11.2	12.5	2.56
Digestive and excretory system (partial)	20.735	15278.4	2133.2	452.7	157.8	24.67
Offal fat	17,454	1956.9	15058.1	64.4	25.1	3.32
Heart and neck sweetbreads	511	206.4	252.5	7.7	3.8	0.86
Liver	4,416	3046.3	115.9	144.1	70.1	14.75
Gall	212	197.5	0.1	0.5	2.2	0.06
Spleen	1,255	968.2	29.7	35.1	16.8	3.00
Pancreas	736	422.4	196.1	15.4	9.8	2.02
Kidneys	1,074	829.5	73.4	22.3	11.3	2.18
Tongue, marketable	1,766	1172.3	237.1	45.6	15.9	2.84
Hair and hide	41.268	23189.7	1490.6	2701.8	480.0	19.40
Head and tail, lean and fat	4.412	2715.8	841.5	127.6	37.9	6.13
Shin and shank, lean and fat	12.706	8717.1	1191.8	424.8	117.8	20.46
Flank and plate, lean and fat	48,946	20515.2	22190.7	934.9	279.0	46.01
Rump, lean and fat	10.484	4675.7	4385.4	212.5	69.9	12.48
Chuck and neck, lean and fat	73,512	46450.8	13372.6	2077.5	675.6	110.27
Round, lean	43.408	31805.9	1978.1	1405.1	444.5	83.34
Round, fat	9,940	2189.8	7023.4	76.0	30.9	3.98
Loin, lean	32,062	21676.2	3539.6	986.2	292.4	54.51
Loin, fat	15,308	1913.0	12759.8	99.5	27.6	3.98
Rib, lean	16,908	11010.3	2527.8	501.7	151.5	26.55
Rib, fat	5,398	806.4	4338.2	45.3	11.4	1.89
Kidney, fat	4,740	212.5	4451.6	8.7	6.2	0.95
Skeleton of feet	7,016	2627.6	1004.3	252.4	1709.5	309.05
Skeleton of head	9,665	4169.7	1252.1	312.1	2166.9	406.32
Skeleton of tail	416	153.8	101.0	13.0	75.3	13.58

Table 39.—Steer 512. Weights of Constituents in Samples, Grams—Cont.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Skeleton of shin	6,074	1649.6	1263.9	220.6	1821.2	327.27
Skeleton of shank	6,156	1968.6	1326.1	217.9	1401.6	252.03
Skeleton of flank and plate	7,788	2865.4	1640.2	236.2	1523.6	279.28
Skeleton of rump	3,264	772.9	1001.4	97.5	857.6	145.12
Skeleton of chuck and neck	16,536	4758.2	3139.5	536.4	5045.1	899.23
Skeleton of round (excl. marrow)	7,430	2134.1	1986.3	209.7	1679.6	301.14
Marrow from skeleton of round	396	39.9	349.7	0.7	2.6	0.52
Skeleton of loin	8,748	2198.9	2134.8	261.3	2330.6	466.62
Skeleton of rib	6,938	2042.3	1132.6	241.1	1991.1	378.40
Horns	1,810	637.6	8.7	127.3	441.7	70.12
Hoofs and dewclaws	1,724	843.1	10.1	135.5	48.1	2.14
Teeth	710	141.4	5.6	15.3	452.4	85.42

Table 40.—Steer 513. Weights of Constituents in Samples, Grams.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	25,680	19947.2	....	881.1	185.4	7.19
Circulatory system	3,485	2704.4	156.8	93.2	31.7	5.47
Respiratory system	4,858	3590.3	341.6	133.2	48.2	7.53
Fat from thoracic cavity	3,942	529.8	3299.7	14.4	7.3	0.95
Brain and spinal cord	748	510.1	115.9	12.9	12.0	3.07
Digestive and excretory system (partial)	25,642	19310.7	1973.7	592.3	266.9	40.26
Offal fat	53,771	3055.8	49939.3	115.6	42.5	5.91
Heart and neck sweetbreads	1,334	538.0	674.3	18.7	11.0	2.64
Liver	5,920	4021.2	185.1	190.9	82.7	19.71
Gall	37	33.8	0.1	0.1	0.4	0.01
Spleen	1,114	842.7	50.6	32.7	14.0	2.70
Pancreas	873	437.5	302.6	16.5	9.5	2.11
Kidneys	1,015	772.1	58.9	25.4	11.5	2.23
Hair and hide	45,286	26069.3	4561.2	2344.9	426.1	24.45
Head and tail, lean and fat	5,390	3038.8	1417.1	131.5	41.5	6.90
Shin and shank, lean and fat	17,798	9924.0	4922.4	411.0	124.1	21.00
Flank and plate, lean and fat	115,774	33830.3	72079.7	1437.9	445.7	75.25
Rump, lean and fat	19,082	6025.1	11211.6	263.0	83.6	15.27
Chuck and neck, lean and fat	110,940	53117.0	41259.7	2387.4	697.8	128.69
Round, lean	50,782	33089.0	7280.6	1473.2	462.6	87.85
Round, fat	19,108	3394.2	14539.1	176.0	38.0	4.59
Loin, lean	44,510	26437.2	9612.8	1236.0	367.7	72.55
Loin, fat	49,928	4444.0	44182.3	182.7	57.4	8.99
Rib, lean	24,744	13754.9	6857.3	635.2	187.3	35.14
Rib, fat	23,608	4201.5	17813.4	96.3	32.6	4.96
Kidney, fat	14,490	566.9	13755.1	22.6	10.7	1.45
Skeleton of feet	7,598	2753.4	1128.8	267.6	1811.1	322.38
Skeleton of head	7,865	3201.6	742.5	259.6	1968.5	460.57
Skeleton of tail	297	116.7	58.7	10.0	51.2	9.00
Skeleton of shin	6,120	1792.6	1091.5	206.7	1672.3	294.43
Skeleton of shank	6,058	1582.6	1206.7	216.3	1792.6	317.02
Skeleton of flank and plate	7,438	3043.8	1121.7	243.8	1519.2	307.86
Skeleton of rump	3,464	845.8	1014.5	104.2	855.2	162.22
Skeleton of chuck and neck	15,526	4969.6	2760.7	544.7	3912.9	785.31
Skeleton of round (excl. marrow)	6,564	1625.0	2011.1	194.8	1625.1	286.58
Marrow from skeleton of round	480	41.6	431.8	0.8	3.9	0.67
Skeleton of loin	8,536	2149.9	2543.6	258.2	2081.3	401.11
Skeleton of rib	7,096	1884.6	1528.4	238.6	2073.2	392.27
Horns	2,144	790.1	16.4	138.3	485.0	89.36
Hoofs and dewclaws	2,180	914.1	19.4	195.2	64.5	5.21
Teeth	874	278.8	9.6	15.8	459.5	87.04

TABLE 41.—STEER 515. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	27,856	22036.1	....	896.1	165.5	6.69
Circulatory system	5,787	2432.4	2808.4	73.8	27.8	4.98
Respiratory system	3,653	2789.2	198.8	98.6	35.4	6.83
Brain and spinal cord	728	509.9	117.1	12.0	11.9	2.88
Digestive and excretory system	36,311	24025.9	6794.2	733.1	309.0	58.82
Offal fat	29,877	2250.3	26976.2	84.0	37.1	4.48
Hair and hide	49,943	27969.6	6267.9	2417.2	927.4	29.47
Head and tail, lean and fat	5.918	3169.8	1807.2	143.0	43.3	7.70
Shin and shank, lean and fat	16,676	9565.5	4461.3	417.2	119.4	20.51
Flank and plate, lean and fat	87,138	27115.6	52220.7	1185.1	338.1	61.87
Rump, lean and fat	15,810	5586.6	8569.7	238.1	75.3	13.44
Chuck and neck, lean and fat	88,134	46944.6	27399.1	2076.4	627.5	111.05
Round, lean	42,942	29067.9	4746.0	1332.1	396.8	76.01
Round, fat	19.058	3339.3	14807.3	149.4	41.0	4.96
Loin, lean	41,620	27036.8	6323.3	1248.2	413.7	75.33
Loin, fat	38,324	4053.2	33197.4	157.9	44.1	6.52
Rib, lean	19.016	11634.6	3976.8	527.9	161.5	28.90
Rib, fat	16,282	1476.9	14374.9	64.2	21.8	3.26
Kidney, fat	9,922	491.2	9369.6	17.7	18.0	1.49
Skeleton of feet, head and tail	18,179	7520.3	2029.0	551.2	4270.3	739.16
Skeleton of shin and shank	13.900	3852.1	3761.8	423.3	3429.1	560.45
Skeleton of flank and plate	6,368	2687.0	1016.6	217.2	1132.2	198.24
Skeleton of rump	4,074	1213.8	104.7	126.1	949.8	165.85
Skeleton of chuck and neck	14,528	4431.0	2254.3	484.2	4295.6	617.88
Skeleton of round	6.344	1499.9	1866.0	191.8	1825.0	310.22
Skeleton of loin	7,784	1969.9	2196.6	231.3	2040.7	350.05
Skeleton of rib	6,464	1686.2	1303.1	211.4	2015.2	282.74
Horns	1,804	733.2	10.7	101.3	427.1	76.18
Hoofs and dewclaws	1,893	1017.5	10.0	139.4	34.5	1.36
Teeth	786	214.8	6.8	14.0	499.1	86.40

TABLE 42.—STEER 523. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	15,287	12309.1	....	426.5	100.7	3.36
Circulatory system	3,044	1615.0	1090.5	51.3	18.2	3.35
Respiratory system	3,371	2652.3	136.7	87.8	33.2	6.37
Brain and spinal cord	797	546.7	140.4	12.9	12.1	2.86
Digestive and excretory system	24,667	18548.1	2548.1	540.2	194.4	38.97
Hair and hide	33,097	20547.0	380.6	1854.4	340.9	16.88
Head and tail, lean and fat	3,100	2113.2	358.8	95.9	28.6	4.77
Shin and shank, lean and fat	8,684	6233.9	524.2	295.4	79.5	14.68
Flank and plate, lean and fat	26,984	16058.2	6184.7	726.7	199.4	37.51
Rump, lean and fat	5,418	2943.6	1585.8	137.2	40.5	8.34
Chuck and neck, lean and fat	50.320	35668.8	5176.9	1502.6	463.5	86.05
Round, lean	33,900	26078.9	783.1	1069.6	353.2	68.48
Loin, lean	25,834	18020.3	2688.3	782.0	237.9	44.43
Rib, lean	12.032	8456.3	1118.6	375.3	111.5	21.42
Round, fat	4,556	1346.0	2743.8	72.0	16.3	2.19
Loin, fat	6,376	1051.9	4969.1	55.0	17.9	2.87
Rib, fat	1,522	358.3	989.0	23.0	6.0	0.90
Kidney, fat	3,110	163.6	2883.8	14.5	5.6	0.47
Offal fat	7,915	1220.3	6433.6	39.2	16.2	2.37
Skeleton of feet, head and tail	13,120	5805.7	1065.3	467.5	2990.8	542.51
Skeleton of shin and shank	8,862	2611.1	1804.7	299.6	2449.0	454.80
Skeleton of flank and plate	3,882	1741.8	415.8	134.7	754.8	134.59
Skeleton of rump	1,770	478.5	358.6	57.9	523.8	196.11
Skeleton of chuck. and neck	9,786	3314.1	1261.8	360.2	2876.5	527.56
Skeleton of round	4,630	1845.1	1231.5	89.9	1950.2	177.79
Skeleton of loin	5,322	1483.4	1260.6	167.4	1438.5	265.09
Skeleton of rib	3,844	1200.0	481.2	138.1	1219.1	221.76
Horns	1,167	539.5	7.3	65.5	218.7	39.87
Hoofs and dewclaws*	1.063	575.1	7.8	76.5	21.6	1.31
Teeth	766	201.6	5.9	16.1	432.0	81.78

*This sample was lost before analysis. The analysis of the hoofs and dewclaws of four animals of the same Group was used.

Table 43.—Steer 524. Weights of Constituents in Samples, Grams.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	17,019	13956.6	....	474.3	127.0	3.74
Circulatory system	2,953	1833.5	662.0	66.2	22.7	3.90
Respiratory system	3,455	2682.3	89.9	96.5	37.1	6.15
Brain and spinal cord	758	555.0	77.7	12.1	10.8	2.56
Digestive and excretory system (partial)	17,924	13280.6	1760.3	412.8	158.6	26.89
Offal fat	5.007	1255.2	3477.1	38.1	16.0	1.75
Heart and neck sweetbreads	541	406.4	40.3	14.1	10.1	2.50
Liver	3,019	2108.5	100.1	92.0	42.5	9.87
Gall	229	217.2	0.2	0.4	1.8	0.07
Spleen	757	596.2	13.8	20.8	10.1	1.97
Pancreas	435	285.5	69.1	11.1	5.4	1.24
Kidneys	766	588.5	43.9	18.6	8.9	1.59
Hair and hide	30,092	17832.2	545.6	1895.8	474.6	17.45
Head and tail, lean and fat	3.364	2229.0	441.6	105.2	34.5	6.02
Shin and shank, lean and fat	8,674	6335.2	485.8	253.7	84.5	14.40
Flank amd plate, lean and fat	19,788	12607.1	3041.8	633.2	188.4	30.47
Rump, lean and fat	4,030	2563.5	691.0	119.2	39.2	7.05
Chuck and neck, lean and fat	46,386	33655.4	2918.6	1465.8	452.3	80.71
Round, lean	37,714	28988.5	1024.3	1228.3	393.4	72.41
Round, fat	2,526	915.9	1262.0	56.5	10.6	1.34
Loin, lean	24,200	17588.6	1099.7	801.0	255.8	46.95
Loin, fat	2,444	459.7	1791.9	30.2	8.6	1.30
Rib, lean and fat	13,144	9238.3	1044.8	435.1	129.1	23.92
Kidney, fat	766	87.6	644.9	3.4	1.4	0.24
Skeleton of feet	6,010	2434.5	781.4	215.9	1473.4	262.94
Skeleton of head and tail	8,318	3820.5	864.2	254.0	1985.3	354.60
Skeleton of shin and shank	10,262	3240.8	1982.3	345.3	2659.9	474.00
Skeleton of flank and plate	5.926	2569.4	905.0	190.3	1135.7	198.22
Skeleton of rump	2.424	831.6	520.0	72.7	542.9	98.34
Skeleton of chuck and neck	12,896	5197.0	2043.2	427.6	2809.5	514.03
Skeleton of round	5,878	1825.5	1665.9	156.7	1334.3	238.82
Skeleton of loin	6,586	1926.5	1771.7	187.4	1600.8	279.64
Skeleton of rib	5,310	1897.5	984.2	157.7	1324.9	235.18
Horns*	1.227	506.9	9.1	78.7	237.5	44.07
Hoofs and dewclaws	1,494	750.6	12.4	112.8	47.7	3.27
Teeth	806	217.4	8.9	15.4	466.4	88.56

*This sample was lost before analysis. The analysis of the horns of a steer of the same age was used.

Table 44.—Steer 525. Weights of Constituents in Samples, Grams.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	13,614	10961.2	....	400.5	89.9	3.58
Circulatory system	1,320	846.0	324.0	22.5	9.4	1.59
Respiratory system	1,658	1303.4	43.7	46.8	18.4	3.20
Brain and spinal cord	711	505.2	99.1	12.4	10.7	2.63
Digestive and excretory system	23,001	17820.9	2103.2	459.8	203.1	35.95
Hair and hide	27,813	17354.2	138.5	1592.0	370.2	15.85
Head and tail, lean and fat	2,788	2072.0	364.7	51.8	27.5	4.40
Shin and shank, lean and fat	7,596	5533.6	404.9	253.5	73.3	13.44
Flank and plate, lean and fat	18,762	11412.4	3790.7	539.0	155.4	27.96
Rump, lean and fat	4.154	2532.3	869.2	114.7	35.9	6.73
Chuck and neck, lean and fat	35,824	25489.1	3024.6	1119.5	340.0	63.77
Round, lean	27,524	21202.8	661.4	858.8	292.9	56.42
Loin, lean	18.710	13964.0	649.1	605.6	196.1	37.42
Rib, lean	11,666	8226.2	1010.2	368.8	114.0	21.12
Round, fat	1,962	641.3	1114.9	31.4	8.5	1.10
Loin, fat	3.758	826.8	2615.2	41.3	11.1	1.50
Rib, fat	664	186.5	409.1	10.7	4.0	0.61
Kidney, fat	1,258	84.6	1134.5	5.9	2.0	0.25
Offal fat	4,961	1043.2	3504.5	63.8	14.5	2.53
Skeleton of feet, head and tail	10,782	4638.5	1077.1	402.8	2352.9	450.32
Skeleton of shin and shank	7,014	2127.6	1342.1	244.4	2071.0	293.89
Skeleton of flank and plate	3,454	1540.9	374.9	116.2	744.9	103.24
Skeleton of rump	1,542	474.9	367.3	49.9	379.5	65.01
Skeleton of chuck and neck	8,450	2885.3	1665.8	261.3	1935.1	363.43
Skeleton of round	4.046	1157.2	1322.5	107.3	881.3	114.34
Skeleton of loin	3,928	1123.2	994.1	118.6	959.8	144.47
Skeleton of rib	3,888	1233.9	701.8	139.7	961.9	169.21
Horns	1,298	634.4	7.1	73.2	217.0	40.77
Hoofs and dewclaws	940	487.9	5.4	74.2	11.8	1.26
Teeth	690	159.6	7.3	13.1	418.9	80.99

TABLE 45.—STEER 526. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	18,957	15151.6	....	585.2	147.3	4.74
Circulatory system	2,413	1527.8	517.2	56.5	19.6	3.50
Respiratory system	3,797	2909.1	124.9	106.3	38.9	5.92
Fat from the thoracic cavity	1,585	340.3	1159.3	11.9	4.5	0.54
Brain and spinal cord	660	483.2	67.7	11.5	11.4	2.77
Digestive and excretory system (partial)	20,541	14971.1	2510.5	437.5	157.8	26.09
Offal fat	11,551	1500.7	9719.5	47.4	20.2	2.08
Heart and neck sweetbreads	439	265.5	106.3	9.9	6.3	1.53
Liver	3,531	2398.3	150.2	114.7	51.9	12.29
Gall	143	132.1	0.2	0.3	1.7	0.04
Spleen	831	652.3	12.4	23.0	12.9	2.47
Pancreas	498	316.0	90.7	11.2	5.8	1.40
Kidneys	922	678.2	83.6	21.7	9.9	1.83
Hair and hide	35,732	20663.1	2041.7	2116.4	514.5	17.87
Head and tail, lean and fat	3,616	2234.4	710.2	105.2	30.1	5.13
Shin and shank, lean and fat	11,644	8261.4	877.6	384.4	104.8	19.10
Flank and plate, lean and fat	39,524	19561.2	13931.8	920.9	268.0	49.41
Rump, lean and fat	8,594	4611.8	2576.6	211.7	63.3	11.9
Chuck and neck, lean and fat	61,228	40068.2	8878.1	1789.7	555.3	101.64
Round, lean	44,614	29839.6	5303.3	1472.3	460.0	85.21
Round, fat	5,016	1136.9	3460.1	83.8	14.3	1.81
Loin, lean	31,440	22620.5	1679.2	1009.2	320.1	59.74
Loin, fat	11,634	1687.9	9298.9	98.9	24.2	3.49
Rib, lean	17,264	12022.8	1728.8	531.2	158.8	28.49
Rib, fat	3,720	641.4	2781.4	43.2	9.6	1.64
Kidney, fat	3,224	292.6	2831.7	11.0	4.4	0.68
Skeleton of feet	6,138	2358.5	850.3	226.0	1440.9	267.25
Skeleton of head and tail	9,165	4249.2	1173.6	274.8	1925.0	351.20
Skeleton of shin and shank	11,612	3228.4	2333.7	377.9	3333.0	608.24
Skeleton of flank and plate	6,588	2645.4	1084.8	209.2	1339.5	249.88
Skeleton of rump	2,838	832.8	726.8	88.2	672.8	121.38
Skeleton of chuck and neck	13,842	4749.6	2415.3	462.2	3405.3	620.40
Skeleton of round	6,352	1718.7	1922.9	171.1	1478.2	274.28
Skeleton of loin	6,844	1995.9	1939.1	193.4	1595.6	293.06
Skeleton of rib	5,690	1804.4	1142.2	188.6	1495.7	270.73
Horns	1,427	589.6	10.6	91.5	276.2	51.26
Hoofs and dewclaws	1,875	1019.9	11.7	136.8	39.9	1.59
Teeth	782	173.2	10.0	15.2	480.7	91.39

TABLE 46.—STEER 527. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	27,382	21615.6	....	899.0	208.7	6.30
Circulatory system	4,903	2645.2	1608.1	94.5	31.1	5.59
Respiratory system	4,326	3172.3	310.9	117.5	44.3	7.18
Fat from thoracic cavity	3,988	412.4	3495.3	13.4	5.1	0.60
Brain and spinal cord	701	490.4	98.6	11.1	10.8	2.58
Digestive and excretory system (partial)	23,818	15915.6	4412.8	494.7	169.1	28.34
Offal fat	48,517	2617.0	45247.0	88.8	57.3	6.31
Heart and neck sweetbreads	1,037	379.8	574.0	12.3	7.6	3.19
Liver	5,720	3882.3	198.6	188.4	90.1	10.52
Spleen	1,226	941.5	26.6	35.6	15.7	2.91
Pancreas	849	353.0	393.1	12.4	7.5	1.72
Kidneys	1,244	937.3	103.0	27.5	12.5	2.40
Hair and hide	46,240	25189.2	5483.6	2458.6	633.0	25.89
Head and tail, lean and fat	5,018	2705.8	1537.3	120.9	34.7	6.17
Shin and shank, lean and fat	17,358	9807.8	4582.2	446.1	130.9	22.57
Flank and plate, lean and fat	118,978	32362.0	77919.9	1305.2	371.2	70.20
Rump, lean and fat	24,020	6792.1	15123.5	296.2	75.7	14.17
Chuck and neck, lean and fat	112,440	52601.7	44206.9	2282.5	693.8	122.56
Round, lean	51,396	33977.4	7160.0	1538.3	444.1	89.94
Round, fat	21,466	3462.3	17027.5	161.6	43.8	4.72
Loin, lean	50,140	30681.7	10276.7	1402.4	425.7	80.73
Loin, fat	52,724	5018.8	46540.0	188.2	67.0	8.96
Rib, lean	25,860	14218.9	7266.1	658.7	203.5	36.46
Rib, fat	24,278	2297.4	21415.1	98.8	32.3	3.88
Kidney, fat	18,964	1028.4	17679.6	35.5	19.3	2.65
Skeleton of feet	7,442	2774.4	1199.3	250.9	1761.1	286.44
Skeleton of head and tail	8,822	3717.2	2189.8	279.2	1918.7	324.30
Skeleton of shin and shank	13,136	3580.4	2794.8	413.7	3726.6	597.69
Skeleton of flank and plate	6,082	2392.3	1121.3	182.2	1187.9	207.03
Skeleton of rump	3,260	810.0	1000.5	96.7	780.0	122.15
Skeleton of chuck and neck	14,870	4172.2	3653.6	458.3	3723.0	586.47
Skeleton of round	6,446	1353.5	2188.7	170.3	1742.5	319.98
Skeleton of loin	7,140	1850.7	1840.8	225.0	1924.2	368.14
Skeleton of rib	6,546	1762.2	1510.4	197.8	1873.6	360.23
Horns	1,266	451.5	9.8	88.0	250.8	46.31
Hoofs and dewclaws	2,174	958.3	20.9	193.8	44.8	3.15
Teeth	872	180.5	12.5	17.0	552.7	120.61

TABLE 47.—STEER 531. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	9,457	7743.6	....	268.7	66.5	3.78
Circulatory system	1,971	1118.0	577.9	38.8	13.3	2.48
Respiratory system	1,915	1500.2	54.0	51.3	20.2	3.91
Brain and spinal cord	573	418.2	77.3	10.1	8.6	2.08
Digestive and excretory system (partial)	11,807	9106.6	1089.8	233.4	79.0	14.29
Offal fat	2,899	751.7	2049.0	18.0	8.4	1.33
Heart and neck sweetbreads	472	320.9	69.8	11.8	8.1	2.02
Liver	2,205	1582.9	42.9	64.4	30.5	7.08
Gall	86	78.8	....	0.2	0.8	0.04
Spleen	481	361.1	20.2	14.2	6.9	1.40
Pancreas	297	199.2	43.9	7.5	3.7	0.86
Kidneys	506	379.9	41.9	11.5	5.3	1.08
Hair and Hide	16,693	10627.6	135.4	957.0	189.6	12.52
Head and tail, lean and fat	1,722	1157.5	242.3	50.3	15.0	2.67
Shin and shank, lean and fat	5,480	3934.2	259.5	197.1	58.7	10.30
Flank and plate, lean and fat	10,854	6553.0	1865.9	331.6	109.1	19.10
Rump, lean and fat	2,506	1553.5	453.9	74.7	24.5	4.43
Chuck and neck, lean and fat	26,902	18808.4	2099.7	880.8	278.2	52.73
Round, lean	21,496	16145.9	393.6	703.4	236.9	44.71
Round, fat	1,490	424.3	904.2	22.7	7.1	1.06
Loin, lean	14,078	10278.5	602.3	466.3	154.9	28.72
Loin, fat	2,264	560.5	1468.5	31.4	9.9	1.70
Rib, lean and fat	6,612	4597.7	500.0	220.7	69.6	12.56
Kidney fat	726	44.0	655.3	4.3	1.7	0.23
Skeleton of feet	3,762	1496.3	540.0	121.6	927.0	166.73
Skeleton of head and tail	4,842	2376.4	390.8	147.3	1009.5	175.72
Skeleton of shin and shank	5,998	1903.2	1100.4	176.2	1644.4	306.68
Skeleton of flank and plate	2,546	1190.8	269.1	82.0	519.3	88.19
Skeleton of rump	1,060	333.0	225.1	34.7	270.7	48.47
Skeleton of chuck and neck	6,098	2286.3	976.6	215.6	1434.6	255.32
Skeleton of round	3,640	1275.1	943.2	97.5	777.6	138.54
Skeleton of loin	2,834	881.1	621.1	93.5	722.5	126.71
Skeleton of rib	2,280	738.4	381.7	85.2	575.2	104.58
Hoofs and dewclaws	790	411.6	6.5	59.9	15.5	0.99
Teeth	426	116.8	3.8	8.5	237.7	45.26

TABLE 48.—STEER 532. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	18,752	15090.3	....	562.0	122.3	6.19
Circulatory system	4,843	2320.4	1949.6	77.7	27.4	5.09
Respiratory system	3,870	3001.2	132.1	102.0	40.7	7.47
Brain and spinal cord	643	465.9	93.0	10.7	10.4	2.52
Digestive and excretory system partial	21,741	15805.9	3039.2	412.6	153.9	29.13
Offal fat	23,697	2263.5	21044.1	57.6	27.5	3.79
Heart and neck sweetbreads	441	218.1	169.6	7.2	4.4	1.05
Liver	5,694	4066.6	135.2	161.9	78.3	17.48
Gall	185	170.7	....	0.4	1.9	0.08
Spleen	884	660.3	44.5	25.5	11.1	2.32
Pancreas	630	353.8	174.4	12.8	7.4	1.85
Kidneys	868	618.4	95.3	21.9	8.8	1.85
Hair and hide	33,988	20244.6	2324.4	1775.9	350.8	24.13
Head and tail, lean and fat	4,260	2571.8	935.1	114.5	34.4	6.21
Shin and shank, lean and fat	12,008	8109.7	1320.6	379.5	112.0	20.05
Flank and plate, lean and fat	44,636	19529.6	18635.1	998.5	292.4	51.78
Rump, lean and fat	8,058	3910.4	2891.5	189.0	57.7	10.72
Chuck and neck, lean and fat	66,204	40908.8	12261.0	1926.5	595.2	103.29
Round, lean	38,064	27369.5	1988.1	1257.6	405.4	76.13
Round, fat	6,064	1316.7	4264.3	67.5	17.9	2.55
Loin, lean	36,136	24719.2	3466.5	1175.1	362.8	66.49
Loin, fat	14,954	1872.2	12472.4	100.8	28.6	4.93
Rib, lean	17,356	11677.1	1993.0	547.8	169.9	30.55
Rib, fat	6,194	967.6	4835.7	52.8	16.6	2.48
Kidney, fat	11,734	383.8	11174.1	17.6	10.0	2.58
Skeleton of feet	6,490	2536.3	931.3	234.1	1547.5	273.94
Skeleton of head and tail	7,120	3304.3	910.4	212.5	1512.7	270.13
Skeleton of shin and shank	10,756	3107.4	2325.1	464.2	2512.3	472.94
Skeleton of flank and plate	5,478	2432.7	1037.9	165.8	819.4	149.99
Skeleton of rump	2,282	659.5	633.1	73.1	517.8	93.20
Skeleton of chuck and neck	13,014	3941.0	3074.4	438.2	3126.9	566.24
Skeleton of round	5,624	1511.0	1914.0	141.4	1169.5	208.82
Skeleton of loin	6,246	1754.9	1827.4	193.2	1377.4	254.46
Skeleton of rib	5,222	1826.1	1175.4	154.1	1163.5	209.35
Horns	228	124.8	1.2	14.4	17.3	3.28
Hoofs and dewclaws	1,406	730.2	9.1	107.6	27.4	2.15
Teeth	494	153.2	4.4	10.6	255.4	50.16

TABLE 49.—STEER 538. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	7,219	5948.5	7.0	197.4	56.7	2.02
Circulatory system	1,670	926.6	479.3	32.3	10.6	1.90
Respiratory system	1,825	1474.6	37.5	45.7	18.6	3.63
Brain and spinal cord	487	362.0	57.2	7.8	7.3	1.69
Digestive and excretory system (partial)	10,290	7822.7	1009.8	217.2	89.2	15.54
Offal fat	3,452	731.2	2639.2	18.8	9.4	1.90
Heart and neck sweetbreads	481	335.8	70.2	11.2	8.0	1.95
Liver	1,978	1394.1	37.9	58.5	27.7	6.23
Gall	122	110.9	0.1	0.3	1.3	0.09
Spleen	331	259.6	5.1	9.5	4.7	0.90
Pancreas	208	144.9	24.2	5.3	3.1	0.73
Kidneys	487	356.6	54.9	11.2	5.2	1.02
Hair and hide	15,342	9870.9	205.9	853.6	163.1	9.67
Head and tail, lean and fat	1,496	991.9	231.0	40.4	13.4	2.21
Shin and shank, lean and fat	4,190	3008.9	241.9	138.0	42.0	7.50
Flank and plate, lean and fat	11,036	6367.8	2589.7	306.1	94.0	17.66
Rump, lean and fat	2,096	1252.3	442.6	55.9	18.7	3.23
Chuck and neck, lean and fat	22.284	15261.6	2665.8	662.1	207.5	38.77
Round, lean	16,324	12401.5	440.6	515.7	178.4	32.97
Round, fat	1,702	519.6	999.6	29.1	7.6	1.16
Loin, lean	12.732	9312.3	715.2	396.9	134.3	25.85
Loin, fat	2,360	470.5	1713.4	23.1	6.9	1.27
Rib, lean	5,196	3683.0	423.5	159.8	52.8	9.92
Rib, fat	426	128.6	240.4	6.2	3.1	0.49
Kidney, fat	622	42.0	565.8	2.1	1.1	0.21
Skeleton of feet	3,166	1350.6	491.6	104.3	589.4	105.81
Skeleton of head	4,001	1991.7	311.8	116.7	863.4	163.60
Skeleton of tail	135	70.8	19.1	4.3	15.2	2.63
Skeleton of shin	2,208	632.3	526.1	62.4	554.4	86.64
Skeleton of shank	2,608	792.0	585.2	88.4	616.9	95.71
Skeleton of flank and plate	2,144	1054.6	311.8	68.6	322.6	52.46
Skeleton of rump	732	250.9	173.8	22.3	162.7	27.79
Skeleton of chuck and neck	5,412	2064.1	917.4	180.6	1297.2	192.40
Skeleton of round	2.556	765.8	823.7	61.9	526.5	81.20
Skeleton of loin	2,696	942.7	625.4	79.3	573.1	112.23
Skeleton of rib	2,154	783.3	357.8	68.5	487.2	86.83
Horns	250	137.3	1.3	14.5	24.9	4.74
Hoofs and dewclaws*	635	423.1	3.0	34.0	6.5	0.43
Teeth†	240	68.83	2.7	4.7	130.0	24.48

TABLE 50.—STEER 540. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	6,967	5732.5	70.5	195.5	50.4	1.81
Circulatory system	1,436	834.8	398.2	29.3	9.7	1.82
Respiratory system	1,501	1194.9	34.7	38.9	15.5	2.97
Brain and spinal cord	512	377.1	61.1	8.3	8.1	1.92
Digestive and excretory system (partial)	9,280	6982.2	998.2	185.1	65.2	11.97
Offal fat	2.307	582.4	1639.3	12.6	6.5	1.08
Heart and neck sweetbreads	408	280.7	63.0	9.2	6.2	1.52
Liver	1,593	1124.5	28.0	45.2	22.5	4.86
Gall	58	54.4	0.04	0.1	0.7	0.02
Spleen	331	257.5	4.5	10.3	4.7	0.90
Pancreas	180	130.0	17.3	4.6	2.6	0.62
Kidneys	363	261.9	38.1	8.6	3.9	0.81
Hair and hide	12,994	8399.6	305.8	666.2	163.2	8.71
Head and tail, lean and fat	1.274	866.2	170.8	34.9	11.3	2.13
Shin and shank. lean and fat	3,762	2793.8	151.9	127.8	39.1	6.96
Flank and plate, lean and fat	8,824	5375.9	1629.0	266.6	77.9	13.94
Rump, lean and fat	1,964	1198.9	384.8	54.1	18.1	3.26
Chuck and neck, lean and fat	17,978	12783.8	1500.6	532.3	177.3	32.00
Round, lean	13,456	10185.9	303.4	431.7	145.6	28.26
Round, fat	810	225.4	504.7	11.0	3.1	0.49
Loin, lean	10,700	7869.3	448.0	340.2	115.0	21.51
Loin. fat	2,308	452.3	1700.8	22.1	6.7	1.34
Rib, lean and fat	5,046	3503.4	488.3	156.2	51.1	9.14
Kidney fat	682	91.4	544.3	7.9	1.3	0.24
Skeleton of feet	2,784	1225.2	337.6	91.5	580.2	99.47
Skeleton of head	3,682	1903.2	259.8	101.4	788.6	149.34
Skeleton of tail	138	76.4	17.2	3.1	13.9	2.44
Skeleton of shin	1,952	618.5	432.5	68.3	472.0	89.03
Skeleton of shank	2.304	763.4	558.2	68.4	486.2	86.63
Skeleton of flank and plate	1,862	990.4	225.0	62.9	225.1	54.04
Skeleton of rump	622	219.0	127.2	18.9	201.9	26.25
Skeleton of chuck and neck	4,896	2021.3	721.7	159.8	962.8	172.93
Skeleton of round	2.350	829.2	643.2	59.3	392.6	65.82
Skeleton of loin	2,550	887.6	698.2	71.0	489.8	91.16
Skeleton of rib	1,824	623.3	342.4	60.1	417.0	74.58
Horns	304	165.0	1.8	16.6	37.9	7.33
Hoofs and dewclaws*	481	320.5	2.2	25.8	4.9	0.32
Teeth†	278	79.7	3.1	5.5	150.6	28.36

*Hoofs and dewclaws of steer 538 and steer 540 were analyzed together.
†Teeth of steer 538 and steer 540 were analyzed together.

TABLE 51.—STEER 541. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	12,470	10239.4	11.1	345.8	84.7	3.37
Circulatory system	2,646	1282.3	1055.2	43.6	15.1	2.78
Respiratory system	2,387	1890.9	47.2	65.4	24.8	5.08
Brain and spinal cord	568	411.6	77.3	9.4	8.7	2.11
Digestive and excretory system (partial)	16,313	11628.7	2398.0	330.2	121.7	21.86
Offal fat	11,009	1289.6	9511.6	32.3	13.8	2.86
Heart and neck sweetbreads	740	484.3	141.7	16.9	10.8	2.72
Liver	3,832	2664.8	95.9	121.0	55.2	13.37
Gall	202	179.8	0.4	0.6	2.4	0.12
Spleen	596	463.0	10.8	17.1	7.9	1.66
Pancreas	390	233.7	91.4	7.9	4.7	1.11
Kidneys	645	473.9	63.9	14.3	6.9	1.38
Hair and hide	26,574	16057.3	970.0	1512.6	292.3	14.62
Head and tail, lean and fat	2,062	1370.6	299.4	60.6	21.0	3.38
Shin and shank, lean and fat	6.830	4693.9	616.1	199.6	65.3	12.16
Flank and plate, lean and fat	24,910	12405.7	8529.4	604.6	178.6	31.64
Rump, lean and fat	4.454	2250.7	1459.8	105.6	31.8	6.10
Chuck and neck, lean and fat	40,480	26418.5	5979.7	1190.9	369.6	66.79
Round, lean	27,000	19957.1	908.8	901.8	294.0	56.16
Round, fat	3,854	817.1	2828.8	38.0	10.9	1.77
Loin, lean	23,416	16848.3	1301.7	757.0	245.9	46.36
Loin, fat	8,088	1202.0	6521.7	63.1	16.5	3.15
Rib, lean	11,588	7956.0	1209.0	362.2	113.1	21.67
Rib, fat	2,434	432.9	1850.8	26.3	7.6	1.44
Kidney, fat	6,056	272.2	5713.8	12.2	5.2	1.21
Skeleton of feet	4,506	1872.3	578.6	154.9	973.7	168.66
Skeleton of head	5,400	2730.2	381.3	161.7	1085.8	197.48
Skeleton of tail	206	98.7	40.4	6.5	22.4	3.90
Skeleton of shin	2,946	851.4	690.0	91.4	799.5	111.89
Skeleton of shank	3,744	1222.7	778.5	109.8	1039.5	141.45
Skeleton of flank and plate	2.864	1487.0	439.0	65.2	339.1	51.52
Skeleton of rump	1,056	319.9	258.3	32.3	268.7	51.25
Skeleton of chuck and neck	7,296	2542.6	1341.7	245.7	1832.0	264.26
Skeleton of round	3,250	876.1	1054.9	105.7	631.5	136.86
Skeleton of loin	3,916	1344.9	968.6	125.9	786.4	152.92
Skeleton of rib	3,162	1001.5	682.3	101.0	807.5	117.82
Horns	468	248.3	3.1	25.0	64.8	12.59
Hoofs and dewclaws	869	505.1	5.2	52.3	10.9	0.53
Teeth	304	142.4	2.9	4.4	123.8	23.79

TABLE 52.—STEER 547. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	8,711	7042.8	....	256.3	62.5	2.53
Circulatory system	1,624	949.1	451.7	31.9	11.1	2.01
Respiratory system	1,868	1474.0	52.6	47.6	21.5	3.64
Brain and spinal cord	459	354.2	41.1	7.1	6.7	1.68
Digestive and excretory system (partial)	11,978	8883.2	1309.1	256.1	124.8	23.00
Offal fat	3,879	700.4	3059.8	23.5	10.0	2.06
Liver	2,851	2051.7	73.6	84.3	38.9	10.43
Spleen	391	301.4	8.7	11.8	5.3	1.17
Pancreas	200	142.8	20.2	4.9	2.9	0.75
Kidneys	450	329.7	38.5	11.5	5.2	1.08
Hair and hide	14,618	9435.3	267.4	779.1	189.3	10.52
Head, tail, shin and shank, lean and fat	8,590	5906.7	1053.2	242.1	77.1	14.86
Flank and plate, lean and fat	14,226	7829.0	3915.4	355.9	112.8	20.91
Rump, lean and fat	2,256	1227.5	622.1	55.6	18.5	3.54
Chuck and neck, lean and fat	23,636	15975.1	2954.7	655.2	217.0	39.47
Round, lean	17,092	12723.3	612.6	550.9	184.4	35.89
Round, fat	2,150	642.3	1304.3	28.9	8.5	1.46
Loin, lean	13,576	9708.5	831.4	432.0	139.8	27.02
Loin, fat	3,972	837.4	2869.7	39.2	11.9	2.26
Rib, lean	6,560	4579.0	618.8	199.6	64.2	1.18
Rib, fat	1,102	276.4	730.5	15.9	5.5	0.83
Kidney, fat	1,630	128.6	1468.7	5.1	2.2	0.24
Skeleton of feet, head, tail, shin and shank	11,966	5383.9	1685.5	399.8	2272.2	418.93
Skeleton of flank and plate	1,958	1044.4	262.8	60.9	230.5	42.45
Skeleton of rump	760	286.6	121.0	25.0	180.0	33.77
Skeleton of chuck and neck	5,120	2252.3	715.9	164.9	1035.6	186.62
Skeleton of round	2,488	902.6	711.8	62.8	430.8	81.06
Skeleton of loin	3,132	1233.5	629.5	91.1	631.3	120.30
Skeleton of rib	2,172	902.1	368.2	72.1	423.0	78.89
Horns, hoofs and dewclaws	737	392.2	9.8	53.9	18.2	1.62
Teeth	310	100.8	2.1	6.8	158.7	29.61

TABLE 53.—STEER 548. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	4,603	3737.5	....	142.7	32.9	0.97
Circulatory system	753	528.5	94.7	19.6	6.4	1.18
Respiratory system	1,084	833.4	33.9	31.5	2.0	2.19
Brain and spinal cord	526	392.6	58.2	8.6	7.5	1.84
Digestive and excretory system (partial)	5,357	4230.5	228.6	127.8	7.1	9.59
Offal fat	845	444.2	310.8	12.4	6.1	1.03
Heart and neck sweetbreads	168	129.5	10.2	4.7	2.7	0.66
Liver	1,104	781.8	20.3	36.3	15.3	3.71
Spleen	215	166.1	2.9	6.7	2.9	0.60
Pancreas	85	64.1	5.3	2.4	1.2	0.28
Kidneys	353	277.3	12.0	8.8	4.4	0.87
Hair and hide	8,358	5466.8	78.0	466.8	112.8	6.52
Head and tail, lean and fat	967	693.2	87.0	25.9	9.2	1.69
Shin and shank, lean and fat	2,462	1842.7	109.5	80.4	24.6	4.31
Flank and plate, lean and fat	4,802	3279.8	366.3	159.4	46.5	8.36
Rump, lean and fat	1,042	756.3	60.4	34.9	11.5	2.13
Chuck and neck, lean and fat	11,136	8421.6	390.4	345.2	117.3	20.82
Round, lean	9,208	6953.3	154.7	309.7	103.0	19.71
Round, fat	520	279.9	149.4	14.2	3.6	0.45
Loin, lean	5,668	4269.4	114.5	186.6	63.9	11.85
Loin, fat	384	157.2	175.0	7.6	2.3	0.37
Rib, lean and fat	3,180	2412.0	87.1	99.6	34.8	6.20
Kidney, fat	284	78.5	182.4	3.9	1.4	0.17
Skeleton of feet	2,496	1138.7	345.1	83.5	459.6	80.25
Skeleton of head	2,989	1702.2	202.8	82.8	511.4	93.65
Skeleton of tail	94	53.3	10.3	3.2	10.0	1.82
Skeleton of shin	1,584	617.4	312.2	51.0	308.7	56.52
Skeleton of shank	1,712	615.7	362.9	61.9	319.6	59.34
Skeleton of flank and plate	1,514	875.8	163.2	48.4	136.0	23.41
Skeleton of rump	570	250.2	90.8	18.5	104.2	18.94
Skeleton of chuck and neck	3,630	1718.4	479.2	112.9	623.5	116.45
Skeleton of round	1,898	767.2	496.8	49.7	311.4	57.26
Skeleton of loin	1,652	726.8	312.9	51.7	281.3	53.36
Skeleton of rib	1,614	753.3	237.1	55.2	265.7	48.50
Horns, hoofs and dewclaws	435	241.8	5.0	30.1	11.3	1.15
Teeth	264	111.2	1.7	5.5	111.3	20.95

TABLE 54.—STEER 550. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	7,080	5760.4	....	203.0	43.1	2.19
Circulatory system	1,163	651.3	347.9	23.1	7.7	1.55
Respiratory system	1,460	1137.0	58.2	36.2	14.6	2.91
Brain and spinal cord	443	333.1	44.7	7.0	6.4	1.55
Digestive and excretory system (partial)	9,156	6653.2	1192.0	179.0	107.7	16.94
Offal fat	2,610	544.9	1949.3	15.3	8.4	2.06
Liver	1,992	1398.4	62.5	59.6	26.4	6.22
Spleen	291	233.4	7.7	8.6	4.3	0.95
Pancreas	200	133.8	31.1	4.9	2.7	0.64
Kidneys	379	285.6	23.7	9.5	4.5	0.96
Hair and hide	10,440	6779.2	127.1	555.4	136.5	8.77
Head, tail, shin, and shank, lean and fat	5,274	3752.2	491.6	149.2	49.9	9.18
Flank and plate, lean and fat	7,896	4868.1	1532.3	225.6	70.1	12.95
Rump, lean and fat	1,662	995.3	344.8	44.7	15.3	2.96
Chuck and neck, lean and fat	15,814	10633.2	2229.6	424.6	150.2	28.47
Round, lean	11,720	8849.2	310.9	400.6	124.6	24.96
Round, fat	944	306.2	546.8	13.6	3.9	0.65
Loin, lean	9,072	6709.2	408.5	281.0	96.1	20.96
Loin, fat	2,134	465.6	1524.7	19.6	7.0	1.39
Rib, lean and fat	4,408	3045.1	486.4	128.9	43.9	8.24
Kidney, fat	756	78.9	656.8	3.4	1.7	0.43
Skeleton of feet, head, tail, shin and shank	9,839	4520.0	1539.4	290.2	1836.8	340.53
Skeleton of flank and plate	1,540	810.0	197.0	49.9	187.3	33.37
Skeleton of rump	700	285.6	133.7	23.7	133.1	25.45
Skeleton of chuck and neck	4,956	2224.1	810.9	153.5	895.2	163.25
Skeleton of round	2,100	776.9	602.5	55.2	355.1	67.35
Skeleton of loin	2,464	948.2	610.0	71.4	438.0	82.30
Skeleton of rib	1,740	730.6	306.7	57.4	322.1	59.23
Horns, hoofs and dewclaws	549	292.1	7.3	40.1	13.5	1.21
Teeth	228	74.1	1.6	5.0	116.7	21.77

TABLE 55.—STEER 552. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	5,219	4163.4	....	157.1	44.6	1.46
Circulatory system	1,056	676.6	219.5	22.9	8.3	1.37
Respiratory system	1,096	853.8	28.7	29.9	13.2	2.25
Brain and spinal cord	466	345.2	53.5	7.3	6.4	1.56
Digestive and excretory system (partial)	5,936	4452.5	566.2	128.2	62.8	10.33
Offal fat	1,784	516.0	1208.8	16.5	6.8	1.23
Heart and neck sweetbreads	265	166.0	62.3	6.2	3.8	0.95
Liver	1,181	821.0	24.4	36.9	15.7	3.98
Spleen	284	221.1	3.7	8.8	3.8	0.79
Pancreas	101	74.0	9.4	2.5	1.3	0.30
Kidneys	316	230.3	38.2	7.3	3.6	0.70
Hair and hide	10,532	7037.8	161.6	508.5	148.0	7.37
Head and tail, lean and fat	1,209	822.2	175.1	29.9	11.3	1.87
Shin and shank, lean and fat	2,976	2216.2	138.0	95.6	29.1	5.12
Flank and plate, lean and fat	6,204	3928.9	1088.0	177.8	54.7	9.00
Rump, lean and fat	1,326	869.6	196.3	38.3	12.9	2.32
Chuck and neck, lean and fat	12,684	9248.5	899.0	378.9	126.1	22.58
Round, lean	9,830	7479.7	192.4	320.0	111.0	20.35
Round, fat	908	404.8	378.3	19.2	5.4	0.61
Loin, lean	7,034	5244.5	25.2	220.2	77.4	13.65
Loin, fat	1,042	233.8	739.7	12.3	4.1	0.64
Rib, lean and fat	4,104	2971.5	264.1	132.7	39.8	7.39
Kidney, fat	500	64.6	422.8	2.7	1.4	0.17
Skeleton of feet	2,861	1243.2	366.9	99.5	559.8	99.56
Skeleton of head	3,052	1652.4	190.3	89.0	574.1	105.39
Skeleton of tail	131	70.6	17.5	3.8	16.8	3.04
Skeleton of shin	1,550	617.2	273.8	55.1	291.3	51.65
Skeleton of shank	1,742	566.8	363.1	53.8	434.1	79.84
Skeleton of flank and plate	1,516	822.8	192.8	51.1	161.5	28.97
Skeleton of rump	640	254.7	110.4	21.1	132.8	23.49
Skeleton of chuck and neck	3,908	1749.0	588.2	126.0	718.3	130.68
Skeleton of round	1,626	541.6	482.5	41.7	322.1	56.65
Skeleton of loin	2,192	899.9	458.4	63.0	402.8	75.78
Skeleton of rib	2,084	912.8	337.4	68.4	365.0	68.90
Horns, hoofs and dewclaws	550	317.3	10.1	35.3	14.8	1.44
Teeth	278	113.8	2.2	5.7	120.2	22.83

TABLE 56.—STEER 554. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	4,197	3402.6	....	121.3	33.6	1.30
Circulatory system	591	428.9	61.5	5.0	5.4	1.00
Respiratory system	907	716.7	22.1	24.4	11.0	2.06
Brain and spinal cord	395	303.5	34.7	7.0	6.2	1.38
Digestive and excretory system (partial)	4,216	3276.5	324.9	89.9	46.3	7.97
Offal fat	644	265.6	327.6	7.7	4.1	0.64
Heart and neck sweetbreads	336	271.1	7.2	8.9	7.1	1.59
Liver	1,166	824.8	30.2	32.8	19.7	4.00
Spleen	202	158.2	2.9	6.0	3.0	0.63
Pancreas	76	53.5	10.1	1.8	1.1	0.21
Kidneys	530	432.0	12.7	11.8	6.1	1.14
Hair and hide	7,400	4885.3	119.5	368.2	106.7	7.10
Head and tail, lean and fat	883	642.6	73.7	24.8	11.1	1.69
Shin and shank, lean and fat	2,304	1715.4	90.9	76.5	25.9	4.06
Flank and plate, lean and fat	4,232	2993.7	376.5	126.8	41.5	7.19
Rump, lean and fat	1,052	741.1	95.6	32.2	12.3	1.87
Chuck and neck, lean and fat	10,530	7882.0	465.0	326.6	131.1	19.90
Round, lean	7,918	6013.7	171.3	260.2	100.6	17.02
Round, fat	520	267.5	169.9	13.9	4.0	0.43
Loin, lean	5,812	4350.1	215.0	185.9	66.9	12.03
Loin, fat	428	127.3	247.7	6.0	2.3	0.34
Rib, lean and fat	2,914	2179.5	100.8	95.0	33.2	5.77
Kidney, fat	240	44.6	181.0	1.7	0.8	0.14
Skeleton of feet	2,403	1117.3	335.9	89.0	425.0	78.91
Skeleton of head	2,229	1330.9	70.4	69.3	375.6	70.26
Skeleton of tail	125	71.0	14.2	4.3	13.8	2.58
Skeleton of shin	1,464	585.7	269.6	47.2	307.2	58.30
Skeleton of shank	1,918	772.3	371.3	62.3	334.8	59.92
Skeleton of flank and plate	1,278	775.5	127.2	42.0	99.1	17.56
Skeleton of rump	732	357.2	92.7	25.4	119.2	21.59
Skeleton of chuck and neck	3,732	1920.5	374.5	117.7	611.6	109.91
Skeleton of round	1,702	684.2	420.4	45.4	271.5	46.07
Skeleton of loin	1,868	963.9	258.7	55.9	280.2	50.25
Skeleton of rib	1,354	690.3	166.7	43.0	207.7	36.02
Horns, hoofs and dewclaws	338	186.8	4.9	25.9	8.1	0.77
Teeth	225	104.2	0.2	6.6	87.1	14.31

TABLE 57.—STEER 555. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	4,529	3626.6	....	141.5	33.4	1.59
Circulatory system	554	393.2	66.8	14.3	4.9	0.88
Respiratory system	937	744.4	26.0	25.2	10.5	1.95
Brain and spinal cord	353	269.6	35.1	6.0	5.4	1.25
Digestive and excretory system (partial)	4,534	3553.6	288.2	105.1	49.5	8.57
Offal fat	462	271.2	144.9	8.0	3.6	0.55
Heart and neck sweetbreads	159	120.8	10.1	4.3	2.1	0.44
Liver	1,240	925.5	31.5	36.4	18.5	4.33
Spleen	167	129.2	2.3	5.2	2.2	0.46
Pancreas	106	80.8	5.8	2.8	1.6	0.31
Kidneys	439	360.0	12.0	9.8	5.2	0.98
Hair and hide	6,580	4543.6	49.7	342.2	97.1	5.86
Head and tail, lean and fat	956	694.8	88.3	25.1	10.1	1.55
Shin and shank, lean and fat	2,688	2071.0	62.7	85.7	28.1	4.87
Flank and plate, lean and fat	4,068	3071.9	139.3	129.3	42.2	7.12
Rump, lean and fat	876	630.5	63.7	25.5	9.4	1.64
Chuck and neck, lean and fat	9,402	7281.9	201.5	294.3	97.9	17.39
Round, lean	7,126	5554.7	96.0	218.0	85.1	14.75
Round, fat	376	221.8	89.5	9.8	2.8	0.34
Loin, lean	4,618	3599.2	79.7	143.4	55.4	9.60
Loin, fat	274	121.0	117.7	6.0	2.3	0.27
Rib, lean and fat	2,512	1949.7	63.7	77.9	29.5	4.75
Kidney, fat	130	42.9	74.6	1.6	0.7	0.12
Skeleton of feet	2,157	1110.0	195.0	87.2	350.5	59.99
Skeleton of head	1,978	1235.0	63.6	56.6	293.0	50.83
Skeleton of tail	74	46.9	4.9	2.7	6.8	1.13
Skeleton of shin	1,454	731.9	160.9	47.0	259.2	46.38
Skeleton of shank	1,704	846.9	235.3	49.1	253.3	45.26
Skeleton of flank and plate	1,236	805.5	70.3	41.6	99.3	16.82
Skeleton of rump	506	288.9	29.9	17.7	81.7	13.99
Skeleton of chuck and neck	3,216	1907.4	165.7	101.1	447.4	79.21
Skeleton of round	1,652	884.9	219.0	46.1	244.5	42.65
Skeleton of loin	1,264	749.6	90.6	39.2	164.4	29.24
Skeleton of rib	1,256	734.7	79.7	41.1	165.7	28.54
Horns, hoofs and dewclaws	298	145.6	2.7	22.6	7.9	0.40
Teeth	190	81.0	0.6	5.5	81.4	13.86

TABLE 58.—STEER 556. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	6,124	4989.4	....	170.1	48.0	2.14
Circulatory system	993	619.2	237.9	21.3	8.5	1.47
Respiratory system	1,272	988.1	43.5	34.3	17.8	2.75
Brain and spinal cord	398	267.1	77.4	6.5	6.4	1.39
Digestive and excretory system (partial)	6,003	4473.6	631.0	132.3	78.3	14.47
Offal fat	1,402	457.3	859.6	13.5	6.3	0.88
Heart and neck sweetbreads	328	250.6	21.6	8.5	67.3	1.48
Liver	1,760	1251.6	61.6	53.9	40.4	6.44
Spleen	300	233.2	7.0	9.0	4.4	0.82
Pancreas	96	69.4	10.2	2.3	1.4	0.29
Kidneys	338	254.6	24.0	8.5	4.5	0.86
Hair and hide	10,314	6836.5	222.1	531.9	142.0	9.08
Head and tail, lean and fat	914	628.3	120.6	25.1	8.2	1.51
Shin and shank, lean and fat	2,808	2070.4	126.6	91.9	27.1	5.19
Flank and plate, lean and fat	6,174	4153.1	824.8	194.1	57.7	10.37
Rump, lean and fat	1,244	862.5	129.2	37.5	12.9	2.38
Chuck and neck, lean and fat	12,406	8971.5	944.7	374.2	154.6	22.33
Round, lean	9,472	7121.0	302.6	311.5	118.5	19.89
Round, fat	686	305.7	298.7	15.1	4.0	0.47
Loin, lean	6,938	5147.0	262.2	226.9	82.5	14.29
Loin, fat	820	214.1	541.5	11.5	4.4	0.52
Rib, lean and fat	3,300	2357.5	238.4	105.1	38.1	6.07
Kidney, fat	420	64.5	338.6	2.5	1.5	0.16
Skeleton of feet	2,589	1202.4	367.0	96.5	459.8	84.89
Skeleton of head	2,610	1478.0	187.6	78.0	460.1	85.37
Skeleton of tail	92	52.4	9.2	3.3	12.3	2.20
Skeleton of shin	1,702	685.5	337.0	55.8	336.6	62.89
Skeleton of shank	1,952	731.1	441.4	66.2	389.8	73.92
Skeleton of flank and plate	1,578	909.9	18.4	52.3	162.0	29.38
Skeleton of rump	608	286.9	80.1	21.5	110.4	20.72
Skeleton of chuck and neck	3,734	1758.9	468.1	130.2	692.5	132.37
Skeleton of round	1,974	753.0	507.8	52.6	329.7	63.40
Skeleton of loin	2,268	1046.8	361.9	71.6	384.0	75.05
Skeleton of rib	1,646	763.2	203.3	54.5	298.9	61.23
Horns, hoofs and dewclaws	390	187.9	4.8	32.4	7.3	0.60
Teeth	218	91.0	0.1	6.4	95.8	15.06

TABLE 59.—STEER 557. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phospnorus
Blood	8,952	7156.3	....	280.7	75.4	2.42
Circulatory system	2,342	1183.1	903.0	38.6	14.4	2.46
Respiratory system	1,972	1519.5	103.7	51.2	22.1	4.00
Brain and spinal cord	551	399.9	68.5	69.9	7.8	1.86
Digestive and excretory system (partial)	9,981	7371.1	1142.4	200.3	104.9	17.57
Offal fat	6,757	942.3	5640.1	29.4	15.5	1.96
Heart and neck sweetbreads	623	422.3	105.2	14.5	10.3	2.22
Liver	3,003	2086.0	56.5	92.6	40.4	9.97
Spleen	485	373.1	16.2	14.0	6.7	1.36
Pancreas	225	145.9	38.6	5.1	2.4	0.56
Kidneys	649	498.1	38.2	15.4	7.5	1.41
Hair and hide	14,100	8900.5	706.7	703.3	165.1	10.01
Head and tail, lean and fat	1,915	1158.1	462.2	45.0	16.2	2.76
Shin and shank, lean and fat	4,196	2861.9	496.3	123.1	38.9	6.42
Flank and plate, lean and fat	15,294	7713.4	5251.2	357.0	119.0	20.34
Rump, lean and fat	2,582	1321.4	848.1	59.8	20.6	3.67
Chuck and neck, lean and fat	22,146	14152.0	3891.9	598.4	211.9	40.53
Round, lean	14,960	11044.1	689.7	459.7	151.3	29.02
Round, fat	2,532	702.5	1611.5	25.8	8.8	1.22
Loin, lean	11,714	8335.1	916.7	347.4	128.6	22.49
Loin, fat	4,472	711.4	3573.1	32.6	11.1	1.70
Rib, lean	6,372	4322.2	763.8	185.1	61.9	10.83
Rib, fat	1,616	316.3	1194.5	15.5	5.8	0.95
Kidney, fat	3,288	266.9	2897.7	11.9	5.1	0.77
Skeleton of feet	3,558	1579.2	426.8	128.1	670.9	124.10
Skeleton of head	3,969	2136.0	248.6	109.2	724.9	130.74
Skeleton of tail	193	102.3	32.4	6.1	20.2	3.77
Skeleton of shin	2,246	826.4	404.6	75.3	477.0	88.96
Skeleton of shank	2,610	962.7	510.0	88.9	523.4	94.61
Skeleton of flank and plate	2,498	1408.7	316.2	78.7	242.5	42.99
Skeleton of rump	960	410.4	128.7	33.0	183.9	35.62
Skeleton of chuck and neck	5,638	2421.1	680.7	191.4	1175.4	212.21
Skeleton of round	2,686	873.1	789.6	69.1	514.8	95.30
Skeleton of loin	2,478	957.2	499.1	73.3	480.3	90.57
Skeleton of rib	2,572	1037.8	432.9	83.3	505.9	92.87
Horns, hoofs and dewclaws	695	373.0	9.8	48.3	17.9	19.39
Teeth	261	104.4	0.7	7.5	120.4	22.53

TABLE 60.—STEER 558. WEIGHTS OF CONSTITUENTS IN SAMPLES, GRAMS.

Description of sample	Sample	Water	Crude fat	Nitrogen	Ash	Phosphorus
Blood	4,666	3902.8	....	117.1	32.3	1.82
Circulatory system	971	643.2	184.8	21.6	7.1	1.39
Respiratory system	1,111	884.7	16.4	29.8	11.7	2.57
Brain and spinal cord	520	393.1	52.0	8.3	7.8	1.94
Digestive and excretory system (partial)	6,510	5075.3	414.4	145.9	64.6	12.24
Offal fat	829	394.6	358.2	11.5	4.2	0.83
Liver	1,352	966.3	28.4	41.9	18.2	4.76
Spleen	193	146.3	2.1	6.4	3.0	0.54
Pancreas	153	116.7	7.9	3.9	2.2	0.57
Kidneys	318	244.2	13.8	8.3	3.8	0.79
Hair and hide	8,138	5266.3	87.7	430.3	92.0	6.75
Head, tail, shin, and shank, lean and fat	4,324	3216.2	238.2	127.5	40.8	7.05
Flank and plate, lean and fat	4,192	2961.7	306.5	135.4	38.7	7.21
Rump, lean and fat	1,030	719.4	99.3	31.8	10.4	2.02
Chuck and neck, lean and fat	11,682	8789.8	481.4	355.3	108.3	21.85
Round, lean	9,664	7456.0	107.6	301.1	101.4	20.58
Round, fat	644	289.8	266.2	14.9	3.9	0.61
Loin, lean	5,962	4468.5	158.1	189.7	61.1	12.52
Loin, fat	600	181.2	356.5	9.3	2.7	0.48
Rib, lean and fat	3,242	2421.1	113.1	102.4	32.1	6.39
Kidney fat	220	40.5	165.4	2.1	0.6	0.12
Skeleton of feet, head, tail, shin and shank	9,785	4475.4	1645.3	303.0	1716.4	318.21
Skeleton of flank and plate	1,092	596.6	137.0	36.1	113.7	20.58
Skeleton of rump	678	288.5	124.6	21.1	126.6	22.94
Skeleton of chuck and neck	4,056	1752.7	733.8	125.3	723.9	131.41
Skeleton of round	2,094	717.6	708.0	47.9	338.4	62.44
Skeleton of loin	2,138	850.3	535.3	54.1	381.4	70.15
Skeleton of rib	1,516	710.8	243.3	50.8	230.3	41.64
Horns, hoofs and dewclaws	443	235.7	5.9	32.4	10.9	0.98
Teeth	274	89.1	1.9	6.0	140.3	26.17

TABLE 61.—COMPOSITION OF CERTAIN PARTS AND OF THE TOTAL ANIMAL.
(3-Months-Old Cattle)

	Percent Water	Percent Fat	Percent Nitrogen	Percent Ash	Percent Phosphorus
Animal 556, Group I					
Lean and fat flesh	70.59	9.14	3.09	1.13	0.184
Bone	46.59	14.37	3.29	17.52	3.332
Blood	81.47	....	2.78	0.78	0.035
Circulatory system	62.36	23.96	2.15	0.86	0.148
Respiratory system	77.68	3.42	2.70	1.40	0.216
Nervous system	67.12	19.45	1.62	1.62	0.349
Digestive and excretory system	74.03	8.56	2.43	1.54	0.276
Hair and Hide	66.28	2.15	5.16	1.38	0.088
Offal fat	32.62	61.31	0.96	0.45	0.063
Total animal	65.23	9.71	3.24	4.88	0.868
Animal 554, Group II					
Lean and fat flesh	73.19	5.94	3.12	1.17	0.191
Bone	49.29	13.30	3.20	16.20	2.932
Blood	81.07	....	2.89	0.80	0.031
Circulatory system	72.58	10.40	2.53	0.91	0.169
Respiratory system	79.02	2.44	2.69	1.21	0.227
Nervous system	76.83	8.78	1.77	1.58	0.350
Digestive and excretory system	76.86	5.94	2.32	1.28	0.238
Hair and hide	66.02	1.62	4.98	1.44	0.096
Offal fat	41.23	50.87	1.20	0.63	0.099
Total animal	67.05	7.35	3.23	4.97	0.866
Animal 555, Group III					
Lean and fat flesh	76.42	3.26	3.08	1.10	0.189
Bone	56.63	7.97	3.21	14.34	2.510
Blood	80.08	....	3.12	0.74	0.035
Circulatory system	70.98	12.06	2.57	0.88	0.159
Respiratory system	79.45	2.78	2.69	1.12	0.210
Nervous system	76.37	9.95	1.71	1.54	0.354
Digestive and excretory system	77.80	5.27	2.46	1.19	0.227
Hair and hide	69.05	0.76	5.20	1.48	0.089
Offal fat	58.69	31.37	1.72	0.78	0.119
Total animal	71.11	4.38	3.25	4.36	0.739

TABLE 62.—COMPOSITION OF CERTAIN PARTS AND OF THE TOTAL ANIMAL.
(5½-Months-Old Cattle)

	Percent Water	Percent Fat	Percent Nitrogen	Percent Ash	Percent Phosphorous
Animal 557, Group I.					
Lean and fat flesh	58.12	24.82	2.48	0.86	0.155
Bone	43.24	15.20	3.18	18.77	3.440
Blood	79.94	....	3.14	0.84	0.027
Circulatory system	50.52	38.56	1.65	0.62	0.105
Respiratory system	77.05	5.26	2.60	1.12	0.203
Nervous system	72.58	12.44	1.79	1.41	0.338
Digestive and excretory system	72.81	9.34	2.29	1.15	0.221
Hair and hide	63.12	5.01	4.99	1.17	0.071
Offal fat	13.95	83.47	0.44	0.23	0.029
Total Animal	56.77	20.99	2.75	4.04	0.731
Animal 552, Group II.					
Lean and fat flesh	77.03	9.45	2.99	0.99	0.175
Bone	43.80	15.87	3.16	18.68	3.399
Blood	79.77	....	3.01	0.85	0.028
Circulatory system	64.07	20.78	2.17	0.79	0.130
Respitatory system	77.90	2.61	2.72	1.21	0.205
Nervous system	74.07	11.48	1.56	1.37	0.335
Digestive and excretory system	73.80	8.71	2.35	1.13	0.210
Hair and hide	66.82	1.53	4.83	1.41	0.070
Offal fat	28.92	67.76	0.92	0.38	0.069
Total animal	63.97	10.48	3.13	5.00	0.880
Animal 548, Group III.					
Lean and fat flesh	73.75	4.73	3.20	1.05	0.192
Bone	46.67	15.25	3.13	16.87	3.086
Blood	81.20	....	3.10	0.72	0.021
Circulatory system	70.18	12.58	2.61	0.84	0.157
Respiratory system	76.88	3.13	2.91	1.11	0.202
Nervous system	74.63	11.06	1.64	1.43	0.350
Digestive and excretory system	77.58	3.84	2.56	1.15	0.216
Hair and hide	65.41	0.93	5.35	1.35	0.078
Offal fat	52.57	36.78	1.46	0.72	0.122
Total animal	66.86	6.88	3.32	4.95	0.882

TABLE 63.—COMPOSITION OF CERTAIN PARTS AND OF THE TOTAL ANIMAL.
(8½-Months-Old Cattle)

	Percent Water	Percent Fat	Percent Nitrogen	Percent Ash	Percent Phosphorous
Animal 547, Group I.					
Lean and fat flesh	63.12	17.92	2.72	0.89	0.156
Bone	43.50	16.29	3.13	18.86	3.486
Blood	80.85	....	2.94	0.72	0.029
Circulatory system	58.44	27.81	1.97	0.68	0.124
Respiratory system	78.91	2.82	2.55	1.15	0.195
Nervous system	77.16	8.96	1.54	1.46	0.367
Digestive and excretory system	73.78	9.14	2.32	1.12	0.230
Hair and hide	64.55	1.83	5.33	1.30	0.072
Offal fat	18.06	78.88	0.61	0.26	0.053
Total Animal	61.01	15.73	2.95	3.93	0.704
Animal 550, Group II.					
Lean and fat flesn	66.53	14.30	2.83	0.94	0.185
Bone	44.11	17.91	3.00	17.86	3.306
Blood	81.36	....	2.87	0.61	0.031
Circulatory system	56.00	29.91	1.99	0.66	0.133
Respiratory system	77.88	3.98	2.48	1.00	0.199
Nervous system	75.20	10.10	1.58	1.44	0.351
Digestive and excretory system	72.35	10.96	2.18	1.21	0.214
Hair and hide	64.94	1.22	5.32	1.31	0.084
Offal fat	20.88	74.69	0.59	0.32	0.079
Total animal	62.40	13.94	2.97	4.39	0.798
Animal 558, Group III.					
Lean and fat flesh	73.49	5.52	3.05	0.96	0.190
Bone	43.97	19.32	2.99	17.00	3.125
Blood	88.67	....	2.51	0.69	0.039
Circulatory system	66.25	19.04	2.22	0.73	0.143
Respiratory system	79.63	1.47	2.69	1.05	0.231
Nervous system	75.60	10.00	1.60	1.51	0.374
Digestive and excretory system	76.81	5.47	2.42	1.08	0.222
Hair and hide	64.71	1.08	5.29	1.13	0.083
Offal fat	47.60	43.21	1.39	0.51	0.106
Total animal	65.95	8.59	3.14	5.01	0.914

TABLE 64.—COMPOSITION OF CERTAIN PARTS AND OF THE TOTAL ANIMAL.
(11-Months-Old Cattle)

	Percent Water	Percent Fat	Percent Nitrogen	Percent Ash	Percent Phosphorus
Animal 541, Group I.					
Lean and fat flesh	58.71	23.09	2.68	0.84	0.156
Bone	37.42	18.81	3.13	22.39	3.646
Blood	82.11	....	2.77	0.68	0.027
Circulatory system	48.46	39.88	1.65	0.57	0.105
Respiratory system	79.22	1.98	2.74	1.04	0.213
Nervous system	72.46	13.61	1.66	1.53	0.371
Digestive and excretory system	70.99	12.33	2.24	0.92	0.186
Hair and hide	60.43	3.65	5.69	1.10	0.055
Offal fat	11.71	86.40	0.29	0.13	0.026
Total animal	56.23	21.08	2.91	3.86	0.630
Animal 538, Group II.					
Lean and fat flesh	67.66	14.01	2.90	0.94	0.176
Bone	38.47	18.49	3.08	21.61	3.622
Blood	82.40	....	2.74	0.79	0.028
Circulatory system	55.48	28.70	1.93	0.63	0.114
Respiratory system	80.80	2.06	2.50	1.02	0.199
Nervous system	74.33	11.75	1.61	1.50	0.348
Digestive and excretory system	75.01	8.65	2.25	1.00	0.190
Hair and hide	64.34	1.34	5.56	1.06	0.063
Offal fat	21.18	76.45	0.54	0.27	0.055
Total animal	61.65	13.73	3.08	4.79	0.799
Animal 540, Group III.					
Lean and fat flesh	67.88	11.72	2.97	0.97	0.179
Bone	40.69	17.48	3.06	19.90	3.692
Blood	82.28	....	2.81	0.72	0.026
Circulatory system	58.13	27.73	2.04	0.68	0.127
Respiratory system	79.61	2.31	2.59	1.03	0.198
Nervous system	73.66	11.94	1.62	1.58	0.375
Digestive and excretory system	74.44	9.41	2.15	0.87	0.169
Hair and hide	64.64	2.35	5.13	1.26	0.067
Offal fat	25.24	71.06	0.55	0.28	0.047
Total animal	62.93	12.13	3.07	4.76	0.846

TABLE 65.—COMPOSITION OF CERTAIN PARTS AND OF THE TOTAL ANIMAL.
(11-Months-Old Cattle)

	Percent Water	Percent Fat	Percent Nitrogen	Percent Ash	Percent Phos-phorus
Animal 505, Group I.					
Lean and fat flesh	53.69	29.68	2.57	0.73	0.148
Bone	35.79	17.56	3.19	23.85	4.403
Blood	82.26	....	2.73	0.33	0.023
Circulatory system	52.90	35.03	1.88	0.59	0.119
Respiratory system	76.83	5.48	2.71	0.95	0.202
Nervous system	73.81	14.74	1.69	1.72	0.411
Digestive and excretory system	73.04	11.03	2.29	1.03	0.223
Hair and hide	62.14	5.34	5.30	0.70	0.066
Offal fat	12.41	85.38	0.34	0.12	0.022
Total animal	53.23	25.06	2.79	4.05	0.749
Animal 503, Group II.					
Lean and fat flesh	63.17	18.39	2.87	0.84	0.163
Bone	38.28	15.06	3.10	23.70	4.378
Blood	82.78	....	2.71	0.34	0.076
Circulatory system	51.90	35.79	1.75	0.56	0.115
Respiratory system	78.71	3.16	2.65	0.98	0.207
Nervous system	73.11	16.11	1.68	1.55	0.394
Digestive and excretory system	73.23	8.86	2.45	1.08	0.230
Hair and hide	67.77	2.57	4.79	0.98	0.066
Offal fat	14.64	81.92	0.52	0.18	0.035
Total animal	59.56	16.36	2.98	4.97	0.913

TABLE 66.—COMPOSITION OF CERTAIN PARTS AND OF THE TOTAL ANIMAL.
(18-Months-Old Cattle)

	Percent Water	Percent Fat	Percent Nitrogen	Percent Ash	Percent Phos-phorus
Animal 532, Group I.					
Lean and fat flesh	53.95	28.72	2.57	0.79	0.142
Bone	33.86	22.22	3.34	22.09	4.016
Blood	80.47	....	3.00	0.65	0.033
Circulatory system	47.92	40.26	1.61	0.57	0.105
Respiratory system	77.55	3.41	2.64	1.05	0.193
Nervous system	72.46	14.46	1.66	1.62	0.392
Digestive and excretory system	71.92	12.02	2.11	0.87	0.177
Hair and hide	59.56	6.84	5.23	1.03	0.071
Offal fat	9.55	88.81	0.24	0.12	0.016
Total animal	51.70	26.74	2.75	3.81	0.680
Animal 531, Group III.					
Lean and fat flesh	68.05	10.03	3.17	1.03	0.189
Bone	38.05	16.48	3.19	23.84	4.268
Blood	81.88	....	2.84	0.70	0.040
Circulatory system	56.72	29.32	1.97	0.68	0.126
Respiratory system	78.34	2.82	2.68	1.05	0.204
Nervous system	72.99	13.50	1.77	1.50	0.363
Digestive and excretory system	75.88	8.25	2.16	0.85	0.169
Hair and hide	63.67	0.81	5.73	1.14	0.075
Offal fat	25.93	70.68	0.62	0.29	0.046
Total animal	62.64	10.75	3.26	5.37	0.950

TABLE 68.—COMPOSITION OF CERTAIN PARTS AND OF THE TOTAL ANIMAL.
(3-Year-Old Cattle)

	Percent Water	Percent Fat	Percent Nitrogen	Percent Ash	Percent Phos-phorus
Animal 515, Group I, 34 mos.					
Lean and fat flesh	42.28	45.22	1.89	0.57	0.103
Bone	32.02	18.72	3.14	25.71	4.153
Blood	79.11	....	3.22	0.59	0.024
Circulatory system	42.03	48.53	1.28	0.48	0.086
Respiratory system	76.35	5.44	2.70	0.97	0.187
Nervous system	70.04	16.09	1.65	1.63	0.395
Digestive and excretory system	66.17	18.71	2.02	0.85	0.162
Hair and hide	56.00	12.55	4.84	1.86	0.059
Offal fat	7.53	90.29	0.28	0.12	0.015
Total animal	43.68	37.51	2.29	3.87	0.614
Animal 507, Group II, 34 mos.					
Lean and fat flesh	60.40	21.48	2.72	0.81	0.151
Bone	32.83	18.05	3.40	25.90	4.004
Blood	78.17	....	3.41	0.67	0.022
Circulatory system	47.12	41.27	1.70	0.54	0.104
Respiratory system	77.47	3.93	2.73	0.95	0.159
Nervous system	70.81	13.74	1.50	1.75	0.418
Digestive and excretory system	70.52	14.08	2.10	0.83	0.150
Hair and hide	60.85	6.21	5.69	1.07	0.049
Offal fat	13.10	83.96	0.41	0.14	0.029
Total animal	56.10	19.61	3.03	5.07	0.792

TABLE 67.—COMPOSITION OF CERTAIN PARTS AND OF THE TOTAL ANIMAL.
(2-Year-Old Cattle)

	Percent Water	Percent Fat	Percent Nitrogen	Percent Ash	Percent Phosphorous
Animal 504, Group I, 21 mos.					
Lean and fat flesh	49.66	35.13	2.29	0.68	0.128
Bone	32.99	17.28	3.31	27.14	4.993
Blood	78.65	....	3.33	0.39	0.022
Circulatory system	51.05	36.05	1.88	0.69	0.116
Respiratory system	67.41	14.90	2.88	0.97	0.181
Nervous system	69.23	15.08	1.79	1.36	0.350
Digestive and excretory system	72.08	12.76	2.04	0.87	0.176
Hair and hide	58.29	8.07	5.52	1.06	0.043
Offal fat	12.76	84.82	0.33	0.15	0.023
Total animal	49.76	29.42	2.64	4.02	0.724
Animal 523, Group II, 26 mos.					
Lean and fat flesh	65.17	16.50	2.83	0.86	0.161
Bone	36.08	15.39	3.35	25.78	4.725
Blood	80.52	....	2.79	0.66	0.022
Circulatory system	53.05	35.82	1.68	0.60	0.110
Respiratory system	78.68	4.05	2.61	0.99	0.189
Nervous system	68.60	17.61	1.62	1.52	0.359
Digestive and excretory system	75.19	10.33	2.19	0.79	0.158
Hair and hide	62.80	1.15	5.60	1.03	0.051
Offal fat	15.42	81.28	0.50	0.20	0.030
Total animal	60.37	15.00	3.10	5.29	0.897
Animal 525, Group III, 26 mos.					
Lean and fat flesh	68.45	11.91	2.97	0.94	0.174
Bone	35.22	18.20	3.34	23.86	3.952
Blood	80.51	....	2.94	0.66	0.026
Circulatory system	64.09	24.54	1.71	0.72	0.121
Respiratory system	78.61	2.63	2.82	1.11	0.193
Nervous system	71.05	13.93	1.74	1.50	0.370
Digestive and excretory system	77.48	9.14	2.00	0.88	0.156
Hair and hide	62.40	0.50	5.72	1.33	0.057
Offal fat	21.03	70.64	1.29	0.29	0.051
Total animal	62.44	11.87	3.23	5.09	0.838

TABLE 69.—COMPOSITION OF CERTAIN PARTS AND OF THE TOTAL ANIMAL.
(40-Months-Old Cattle)

	Percent Water	Percent Fat	Percent Nitrogen	Percent Ash	Percent Phosphorous
Animal 527, Group I.					
Lean and fat flesh	37.34	51.80	1.63	0.49	0.089
Bone	30.39	23.73	3.08	25.27	4.302
Blood	78.94	....	3.28	0.76	0.023
Circulatory system	53.95	32.80	1.93	0.64	0.114
Respiratory system	73.33	7.19	2.72	1.02	0.166
Nervous system	69.96	14.06	1.58	1.54	0.368
Digestive and excretory system	66.12	16.84	2.27	0.89	0.145
Hair and hide	54.48	11.86	5.32	1.37	0.056
Offal fat	5.39	93.26	0.18	0.12	0.013
Thoracic fat	10.30	87.65	0.34	0.13	0.015
Total animal	38.63	45.45	2.02	3.03	0.507
Animal 526, Group II.					
Lean and fat flesh	59.20	22.38	2.76	0.83	0.152
Bone	34.14	19.67	3.17	24.16	4.425
Blood	79.93	....	3.09	0.78	0.025
Circulatory system	63.32	21.43	2.34	0.81	0.145
Respiratory system	76.62	3.29	2.80	1.03	0.156
Nervous system	73.22	10.26	1.75	1.73	0.420
Digestive and excretory system	72.16	10.98	2.30	0.92	0.161
Hair and hide	57.83	5.71	5.92	1.44	0.050
Offal fat	12.99	84.14	0.41	0.18	0.018
Thoracic fat	21.47	73.14	0.75	0.29	0.034
Total animal	55.33	20.24	3.04	4.92	0.877
Animal 524, Group III.					
Lean and fat flesh	70.33	8.86	3.15	0.98	0.175
Bone	37.33	18.10	3.16	23.37	4.175
Blood	82.01	....	2.79	0.75	0 022
Circulatory system	62 09	22 42	2.24	0.77	0.132
Respiratory system	77.64	2 60	2.79	1.07	0.178
Nervous system	73.22	10 26	1 60	1.42	0 338
Digestive and excretory system	73.86	8.57	2.41	1.00	0.186
Hair and hide	59.26	1.81	6 30	1 58	0.058
Offal fat	25.07	69.44	0.76	0.32	0.035
Thoracic fat	Not enoug	h to separa	te.		
Total animal	62 43	10.50	3.35	5.79	1 008

TABLE 70.—COMPOSITION OF CERTAIN PARTS AND OF THE TOTAL ANIMAL.
(45-Months-Old. Cattle)

	Percent Water	Percent Fat	Percent Nitrogen	Percent Ash	Percent Phos-phorus
Animal 513, Group I.					
Lean and fat flesh	38.66	49.37	1.70	0.51	0.093
Bone	31.16	20.30	3.30	25.14	4.854
Blood	77.68	....	3.43	0.72	0.028
Circulatory system	77.60	4.50	2.67	0.91	0.157
Respiratory system	73.91	7.03	2.74	0.99	0.155
Nervous system	68.19	15.50	1.72	1.60	0.410
Digestive and excretory system	72.23	9.03	2.44	1.10	0.194
Hair and hide	57.57	10.07	5.18	0.94	0.054
Offal fat	5.68	92.87	0.22	0.08	0.011
Thoracic fat	13.44	83.71	0.37	0.19	0.024
Total animal	39.91	42.85	2.10	3.20	0.599
Animal 502, Group II.					
Lean and fat flesh	61.63	18.22	2.91	0.84	0.156
Bone	33.00	19.18	3.35	24.89	4.408
Blood	77.43	....	3.49	0.72	0.023
Circulatory system	68.29	14.51	2.59	0.68	0.138
Respiratory system	76.17	3.06	2.83	1.04	0.166
Nervous system	69.10	14.60	1.72	1.79	0.414
Digestive and excretory system	75.18	6.15	2.59	1.29	0.174
Hair and hide	57.30	3.10	6.57	0.98	0.059
Offal fat	10.65	86.18	0.47	0.19	0.023
Thoracic fat	21.50	73.48	0.75	0.30	0.041
Total animal	56.60	16.97	3.28	5.09	0.887
Animal 509, Group III.					
Lean and fat flesh	63.17	16.96	2.89	0.85	0.160
Bone	33.59	18.43	3.42	24.78	4.466
Blood	78.05	....	3.43	0.69	0.023
Circulatory system	69.95	12.26	2.59	0.92	0.167
Respiratory system	77.03	2.88	3.00	1.01	0.176
Nervous system	66.87	17.66	1.68	1.58	0.379
Digestive and excretory system	71.81	10.58	2.37	1.01	0.168
Hair and hide	58.97	2.48	6.27	1.02	0.046
Offal fat	11.36	85.89	0.53	0.18	0.024
Thoracic fat	19.81	76.10	0.72	0.30	0.043
Total animal	57.72	16.27	3.23	5.01	0.887

TABLE 71.—COMPOSITION OF CERTAIN PARTS AND OF THE TOTAL ANIMAL.
(4-Year-Old Cattle)

	Percent Water	Percent Fat	Percent Nitrogen	Percent Ash	Percent Phos-phorus
Animal 501, Group I.					
Lean and fat flesh	36.25	53.12	1.46	0.49	0.087
Bone	32.09	17.72	3.36	26.34	4.808
Blood	77.98	....	3.29	0.86	0.025
Circulatory system	60.00	24.55	2.24	0.74	0.125
Respiratory system	76.58	3.35	2.87	1.04	0.172
Nervous system	70.40	13.27	1.67	1.84	0.392
Digestive and excretory system	70.34	12.06	2.35	0.95	0.169
Hair and hide	51.43	13.24	5.49	1.52	0.049
Offal fat	7.49	91.06	0.21	0.10	0.012
Thoracic fat	18.83	76.65	0.61	0.24	0.026
Total animal	38.75	44.34	2.00	3.33	0.587
Animal 512, Group II.					
Lean and fat flesh	54.96	28.29	2.48	0.77	0.133
Bone	31.56	20.31	3.23	25.62	4.698
Blood	79.95	....	3.07	0.79	0.023
Circulatory system	54.88	30.62	2.14	0.84	0.117
Respiratory system	75.49	4.67	2.80	1.08	0.164
Nervous system	72.06	11.12	1.69	1.87	0.385
Digestive and excretory system	72.04	9.89	2.36	0.94	0.164
Hair and hide	56.19	3.61	6.55	1.16	0.047
Offal fat	11.21	86.27	0.37	0.14	0.019
Thoracic fat	12.23	85.52	0.26	0.14	0.015
Total animal	51.88	24.09	2.93	5.10	0.906
Animal 500, Group III.					
Lean and fat flesh	63.11	17.23	2.96	0.89	0.156
Bone	33.05	22.09	3.19	23.55	4.208
Blood	79.04	....	3.19	0.79	0.022
Circulatory system	61.58	22.27	2.26	0.80	0.127
Respiratory system	76.50	2.70	2.84	1.15	0.172
Nervous system	62.77	21.72	1.67	1.75	0.371
Digestive and excretory system	73.06	9.29	2.41	1.00	0.164
Hair and hide	59.33	1.32	6.28	1.07	0.044
Offal fat	13.50	83.56	0.42	0.18	0.020
Thoracic fat	17.04	71.39	0.49	0.24	0.024
Total animal	57.25	17.21	3.20	5.08	0.884

TABLE 72.—COMPOSITION OF THE TOTAL BEEF ANIMAL ON ANALYTICAL, EMPTY, AND FAT-FREE BASES.

Group	Age	Basis	% Water	% Fat	% Nitrogen	% Ash	% Phosphorus
Embryo	185 days	Analytical	84.801	2.363	1.673	1.776	0.283
Embryo	185 days	Fat-free	86.853	....	1.713	1.819	0.290
Embryo	232 days	Analytical	78.700	2.573	2.011	3.180	0.370
Embryo	232 days	Fat-free	80.778	....	2.064	3.264	0.380
Embryo	279 days	Analytical	74.192	3.384	2.735	4.062	0.688
Embryo	279 days	Fat-free	76.791	....	2.831	4.204	0.712
Calves	at birth	Analytical	72.807	3.648	2.926	4.523	0.841
Calves	at birth	Live weight	73.583	3.544	2.843	4.394	0.817
Calves	at birth	Fat-free empty	76.287	....	2.947	4.555	0.847
I	3 months	Analytical	65.226	9.712	3.243	4.875	0.868
I	3 months	Empty	66.028	9.488	3.168	4.763	0.848
I	3 months	Fat-free empty	72.949	....	3.500	5.262	0.937
II	3 months	Analytical	67.051	7.348	3.255	4.971	0.866
II	3 months	Empty	67.562	7.234	3.175	4.894	0.853
II	3 months	Fat-free empty	72.830	....	3.422	5.276	0.919
III	3 months	Analytical	71.108	4.377	3.247	4.356	0.739
III	3 months	Empty	71.517	4.315	3.201	4.295	0.729
III	3 months	Fat-free empty	74.742	....	3.345	4.488	0.761
I	5½ months	Analytical	56.771	20.988	2.753	4.039	0.731
I	5½ months	Empty	57.213	20.773	2.725	3.998	0.723
I	5½ months	Fat-free empty	72.214	....	3.439	5.046	0.913
II	5½ months	Analytical	63.966	10.479	3.130	4.996	0.880
II	5½ months	Empty	64.388	10.356	3.093	4.937	0.870
II	5½ months	Fat-free empty	71.827	....	3.451	5.508	0.970
III	5½ months	Analytical	66.863	6.884	3.315	4.947	0.882
III	5½ months	Empty	67.800	6.689	3.221	4.807	0.857
III	5½ months	Fat-free empty	72.661	....	3.452	5.152	0.919
I	8½ months	Analytical	61.009	15.728	2.952	3.931	0.704
I	8½ months	Empty	61.233	15.637	2.935	3.908	0.700
I	8½ months	Fat-free empty	72.584	....	3.479	4.633	0.830
II	8½ months	Analytical	62.402	13.936	2.974	4.389	0.798
II	8½ months	Empty	63.055	13.695	2.922	4.312	0.784
II	8½ months	Fat-free empty	73.060	....	3.386	4.997	0.908
III	8½ months	Analytical	65.947	8.590	3.135	5.010	0.914
III	8½ months	Empty	66.509	8.437	3.079	4.921	0.897
III	8½ months	Fat-free empty	72.637	....	3.363	5.374	0.980
I	11 months	Analytical	56.225	21.078	2.905	3.862	0.630
I	11 months	Empty	57.556	20.437	2.817	3.744	0.610
I	11 months	Fat-free empty	72.340	....	3.540	4.706	0.767
I	11 months	Analytical	53.228	25.061	2.785	4.049	0.749
I	11 months	Empty	54.424	24.421	2.714	3.946	0.730
I	11 months	Fat-free empty	72.009	....	3.591	5.220	0.966
II	11 months	Analytical	61.651	13.731	3.076	4.785	0.799
II	11 months	Empty	63.006	13.245	2.967	4.616	0.771
II	11 months	Fat-free empty	72.626	....	3.420	5.320	0.889
II	11 months	Analytical	59.557	16.361	2.983	4.969	0.913
II	11 months	Empty	60.371	16.031	2.923	4.869	0.895
II	11 months	Fat-free empty	71.897	....	3.481	5.799	1.066
III	11 months	Analytical	62.925	12.125	3.068	4.764	0.846
III	11 months	Empty	64.800	11.512	2.913	4.532	0.803
III	11 months	Fat-free empty	73.231	....	3.291	5.111	0.908

TABLE 73.—COMPOSITION OF THE TOTAL BEEF ANIMAL ON ANALYTICAL, EMPTY, AND FAT-FREE BASES.

Group	Age	Basis	% Water	% Fat	% Nitrogen	% Ash	% Phosphorus
I	18 months	Analytical	51.695	26.740	2.748	3.808	0.680
I	18 months	Empty	53.038	25.997	2.672	3.702	0.661
I	18 months	Fat-free empty	71.671	....	3.611	5.003	0.894
III	18½ months	Analytical	62.641	10.747	3.258	5.367	0.950
III	18½ months	Empty	65.411	9.951	3.017	4.969	0.879
III	18½ months	Fat-free empty	72.639	....	3.350	5.518	0.976
I	21 months	Analytical	49.762	29.420	2.639	4.015	0.724
I	21 months	Empty	50.933	28.735	2.577	3.921	0.708
I	21 months	Fat-free empty	71.469	....	3.616	5.502	0.993
II	26 months	Analytical	60.368	15.001	3.095	5.290	0.897
II	26 months	Empty	61.960	14.398	2.971	5.077	0.861
II	26 months	Fat-free empty	72.382	....	3.470	5.931	1.006
III	26 months	Analytical	62.444	11.871	3.231	5.088	0.838
III	26 months	Empty	64.115	11.344	3.087	4.861	0.801
III	26 months	Fat-free empty	72.318	....	3.482	5.483	0.903
I	34 months	Analytical	43.684	37.509	2.286	3.873	0.614
I	34 months	Empty	46.601	35.566	2.167	3.672	0.582
I	34 months	Fat-free empty	72.324	....	3.364	5.699	0.904
II	34 months	Analytical	56.102	19.613	3.031	5.071	0.792
II	34 months	Empty	58.014	18.759	2.899	4.850	0.758
II	34 months	Fat-free empty	71.408	....	3.568	5.970	0.933
I	39½ months	Analytical	38.628	45.446	2.019	3.026	0.507
I	39½ months	Empty	39.827	44.558	1.980	2.967	0.497
I	39½ months	Fat-free empty	71.836	....	3.571	5.352	0.897
II	40 months	Analytical	55.333	20.242	3.039	4.924	0.877
II	40 months	Empty	56.556	19.688	2.956	4.789	0.853
II	40 months	Fat-free empty	70.421	....	3.680	5.963	1.062
III	40½ months	Analytical	62.430	10.499	3.353	5.794	1.008
III	40½ months	Empty	63.491	10.202	3.258	5.630	0.979
III	40½ months	Fat-free empty	70.705	....	3.628	6.270	1.091
I	44½ months	Analytical	39.912	42.850	2.103	3.201	0.599
I	44½ months	Empty	41.396	41.792	2.051	3.122	0.585
I	44½ months	Fat-free empty	71.117	....	3.524	5.363	1.004
II	44½ months	Analytical	56.599	16.972	3.281	5.086	0.887
II	44½ months	Empty	57.625	16.571	3.203	4.966	0.866
II	44½ months	Fat-free empty	69.071	....	3.840	5.952	1.038
III	45 months	Analytical	57.715	16.266	3.234	5.005	0.887
III	45 months	Empty	58.369	16.015	3.184	4.928	0.873
III	45 months	Fat-free empty	69.498	....	3.791	5.867	1.040
I	47 months	Analytical	38.752	44.340	1.999	3.329	0.587
I	47 months	Empty	39.836	43.556	1.963	3.270	0.577
I	47 months	Fat-free empty	70.576	....	3.478	5.793	1.022
II	48 months	Analytical	51.879	24.091	2.927	5.098	0.906
II	48 months	Empty	52.666	23.697	2.879	5.014	0.891
II	48 months	Fat-free empty	69.022	....	3.773	6.572	1.167
III	48 months	Analytical	57.254	17.209	3.200	5.078	0.884
III	48 months	Empty	58.142	16.852	3.134	4.972	0.866
III	48 months	Fat-free empty	69.926	....	3.769	5.980	1.041

TABLE 74.—COMPOSITION OF BEEF FLESH ON FAT-FREE BASIS.

Group	Age months	Animal	Sample	% Water	% Nitrogen	% Ash	% Phosphorus
III	48	500	Round, lean	76.704	3.236	1.048	0.198
III	48	500	Loin, lean	76.159	3.374	1.095	0.201
III	48	500	Rib, lean	76.573	3.645	1.060	0.194
III	48	500	Lean and fat composite	76.709	3.511	1.117	0.196
I	47	501	Round, lean	77.117	3.409	1.056	0.204
I	47	501	Loin, lean	76.228	3.489	1.037	0.199
I	47	501	Rib, lean	75.900	3.556	1.019	0.192
I	47	501	Lean and fat composite	76.537	3.331	1.182	0.183
II	44½	502	Round, lean	75.199	3.446	1.012	0.203
II	44½	502	Loin, lean	76.057	3.475	1.061	0.217
II	44½	502	Rib, lean	73.826	3.413	0.994	0.182
II	44½	502	Lean and fat composite	76.098	3.616	1.029	0.195
II	11	503	Round and rump lean	76.776	3.540	1.076	0.214
II	11	503	Loin, lean	77.548	3.481	1.074	0.208
II	11	503	Rib, lean	77.618	3.513	1.033	0.206
I	21	504	Round, lean	76.561	3.533	1.083	0.214
I	21	504	Loin, lean	76.236	3.476	1.078	0.206
I	21	504	Rib, lean	76.722	3.565	1.008	0.202
I	11	505	Round and rump, lean	76.286	3.674	1.078	0.221
I	11	505	Loin, lean	75.752	3.595	1.070	0.218
I	11	505	Rib, lean	76.430	3.668	1.041	0.218
II	34	507	Round, lean	77.182	3.428	1.041	0.204
II	34	507	Loin, lean	76.924	3.040	1.058	0.201
II	34	507	Rib, lean	76.843	3.417	1.068	0.198
III	45	509	Round, lean	76.862	3.364	1.049	0.205
III	45	509	Loin, lean	76.527	3.410	1.045	0.198
III	45	509	Rib, lean	76.041	3.283	1.026	0.091
III	45	509	Lean and fat composite	76.359	3.718	1.039	0.194
II	48	512	Round, lean	76.770	3.392	1.073	0.201
II	48	512	Loin, lean	75.997	3.458	1.025	0.191
II	48	512	Rib, lean	76.566	3.489	1.053	0.185
II	48	512	Lean and fat composite	76.136	3.496	1.074	0.188
I	44½	513	Round, lean	76.064	3.387	1.063	0.202
I	44½	513	Loin, lean	75.757	3.542	1.054	0.208
I	44½	513	Rib, lean	76.900	3.551	1.047	0.196
I	44½	513	Lean and fat composite	77.369	3.345	1.088	0.194
I	34	515	Round, lean	76.102	3.487	1.039	0.199
I	34	515	Loin, lean	76.599	3.536	1.172	0.213
I	34	515	Rib, lean	76.851	3.487	1.066	0.191
II	26	523	Round, lean	78.748	3.230	1.067	0.207
II	26	523	Loin, lean	77.856	3.379	1.028	0.192
II	26	523	Rib, lean	77.486	3.439	1.022	0.196

TABLE 75.—COMPOSITION OF BEEF FLESH ON FAT-FREE BASIS.

Group	Age months	Animal	Sample	% Water	% Nitrogen	% Ash	% Phosphorus
III	40½	524	Round, lean	79.010	3.348	1.072	0.197
III	40½	524	Loin, lean	76.140	3.468	1.107	0.203
III	40½	524	Rib lean and fat	76.354	3.596	1.067	0.198
III	40½	524	Lean and fat of animal	75.735	3.509	1.102	0.201
III	26	525	Round, lean	78.931	3.197	1.090	0.210
III	26	525	Loin, lean	77.316	3.353	1.086	0.207
III	26	525	Rib, lean	77.199	3.461	1.070	0.198
II	40	526	Round, lean	75.907	3.745	1.170	0.217
II	40	526	Loin, lean	76.008	3.391	1.075	0.201
II	40	526	Rib, lean	77.391	3.419	1.022	0.183
II	40	526	Lean and fat of animal	76.605	3.595	1.093	0.186
I	39½	527	Round, lean	76.903	3.477	1.004	0.203
I	39½	527	Loin, lean	76.967	3.518	1.068	0.203
I	39½	527	Rib, lean	76.471	3.542	1.095	0.196
I	39½	527	Lean and fat of animal	76.535	3.390	1.073	0.191
I*	38	529	Rib, lean	76.958	3.474	1.023	0.192
III	18½	531	Round, lean	76.503	3.333	1.123	0.212
III	18½	531	Loin, lean	76.274	3.460	1.149	0.213
III	18½	531	Rib lean and fat	75.222	3.611	1.138	0.206
III	18½	531	Lean and fat of carcass	74.007	3.686	1.218	0.227
I	18	532	Round, lean	75.867	3.486	1.124	0.211
I	18	532	Loin, lean	75.664	3.597	1.111	0.204
I	18	532	Rib, lean	76.008	3.565	1.106	0.199
I	18	532	Lean and fat of carcass	74.809	3.747	1.157	0.209
II	11	538	Round, lean	78.078	3.247	1.123	0.208
II	11	538	Loin, lean	77.494	3.303	1.118	0.215
II	11	538	Rib, lean	77.170	2.348	1.107	0.208
II	11	538	Lean and fat of carcass, excl. kidney fat	77.379	3.379	1.136	0.205
III	11	540	Round, lean	77.444	3.282	1.107	0.215
III	11	540	Loin, lean	76.759	3.318	1.122	0.210
III	11	540	Rib lean and fat	76.867	3.428	1.122	0.200
III	11	540	Lean and fat of carcass, excl. kidney fat	76.910	3.304	1.102	0.191
I	11	541	Round, lean	76.490	3.456	1.127	0.215
I	11	541	Loin, lean	76.187	3.423	1.112	0.210
I	11	541	Rib, lean	76.654	3.490	1.090	0.209
I	11	541	Lean and fat of carcass, excl. of kidney fat	76.264	3.686	1.129	0.212
I	8½	547	Round, lean	77.207	3.343	1.119	0.218
I	8½	547	Loin, lean	76.177	3.390	1.097	0.212
I	8½	547	Rib, lean	77.071	3.360	1.081	0.199
I	8½	547	Lean and fat composite	76.768	3.348	1.094	0.197
III	5½	548	Round, lean	76.804	3.420	1.137	0.218
III	5½	548	Loin, lean	76.878	3.360	1.151	0.213
III	5½	548	Rib lean and fat	77.983	3.221	1.124	0.200
III	5½	548	Lean and fat composite	77.576	3.238	1.095	0.198
III	55	549	Rib, lean	77.060	3.542	1.164	0.206

*Maintenance one year. Then full feed.

TABLE 76.—COMPOSITION OF BEEF FLESH ON FAT-FREE BASIS.

Group	Age months	Animal	Sample	% Water	% Nitrogen	% Ash	% Phosphorus
II	8½	550	Round, lean	77.563	3.511	1.092	0.219
II	8½	550	Loin, lean	77.442	3.243	1.109	0.242
II	8½	550	Rib lean and fat	77.651	3.287	1.120	0.210
II	8½	550	Lean and fat composite	77.704	3.194	1.056	0.207
II	5½	552	Round, lean	77.609	3.320	1.152	0.211
II	5½	552	Loin, lean	77.334	3.248	1.142	0.201
II	5½	552	Rib, lean and fat	77.385	3.455	1.036	0.192
II	5½	552	Lean and fat composite	77.421	3.237	1.135	0.187
II	3	554	Round, lean	77.629	3.359	1.299	0.220
II	3	554	Loin, lean	77.723	3.322	1.194	0.215
II	3	554	Rib, lean and fat	77.473	3.378	1.179	0.205
II	3	554	Lean and fat composite	77.986	3.231	1.257	0.201
III	3	555	Round, lean	79.013	3.101	1.210	0.210
III	3	555	Loin, lean	79.308	3.160	1.221	0.212
III	3	555	Rib, lean and fat	79.634	3.182	1.205	0.194
III	3	555	Lean and fat composite	79.372	3.150	1.087	0.193
I	3	556	Round, lean	77.660	3.398	1.292	0.217
I	3	556	Loin, lean	77.099	3.398	1.236	0.214
I	3	556	Rib, lean and fat	77.002	3.432	1.243	0.198
I	3	556	Lean and fat composite	77.809	3.333	1.283	0.196
I	5½	557	Round, lean	77.392	3.222	1.060	0.203
I	5½	557	Loin. lean	77.196	3.218	1.191	0.208
I	5½	557	Rib, lean	77.069	3.301	1.088	0.193
I	5½	557	Lean and fat composite	77.549	3.345	1.292	0.200
III	8½	558	Round, lean	78.020	3.151	1.061	0.215
III	8½	558	Loin, lean	76.992	3.269	1.053	0.216
III	8½	558	Rib, lean and fat	77.379	3.271	1.026	0.204
III	8½	558	Lean and fat composite	77.830	3.203	1.006	0.204
Jersey	6 days	22A	Flesh	78.477	3.743	1.062	0.204
High Plane	Newborn	562B	Flesh	79.108	3.118	1.110	0.175
High Plane	Newborn	562C	Flesh	80.539	2.724	1.031	0.180
Medium Plane	Newborn	565A	Flesh	80.318	2.760	0.951	0.176
Medium Plane	Newborn	563A	Flesh	79.401	2.921	1.047	0.163
Medium Plane	Newborn	564B	Flesh	79.925	2.926	0.989	0.178
Medium Plane	Newborn	565B	Flesh	79.874	2.909	1.091	0.187
Medium Plane	Newborn	564C	Flesh	79.302	2.897	1.071	0.191
Low Plane	Newborn	568B	Flesh	82.931	2.272	0.896	0.146
Low Plane	Newborn	567B	Flesh	80.332	2.746	1.119	0.180
Low Plane	Newborn	566B	Flesh	82.039	2.806	1.049	0.150
Low Plane	Newborn	568C	Flesh	79.293	2.841	1.057	0.186
High and Medium Plane	Newborn	Average	Flesh	79.794	2.902	1.051	0.179
Low Plane	Newborn	Average	Flesh	81.149	2.666	1.030	0.166

TABLE 77.—EMPTY WEIGHT AT START.

Animal	Age atfirst feeding (days)	Live Weight at first feeding (pounds)	Live weight (kilograms)	Empty weight (per cent)	Empty weight (kilograms)
500	32	118.5	53.750	0.950	51.1
501	10	98.0	44.452	0.967	43.0
502	15	110.6	50.167	0.953	47.8
503	23	158.6	71.939	0.920	66.2
504	21	147.7	66.995	0.927	62.1
505	21	127.1	57.651	0.943	54.4
507	19	93.2	42.275	0.970	41.0
509	15	107.8	48.897	0.957	46.8
512	28	168.5	76.430	0.912	69.7
513	14	106.7	48.398	0.957	46.3
515	19	114.0	51.709	0.950	49.1
523	23	132.2	59.965	0.940	56.4
524	19	145.4	65.952	0.930	61.3
525	36	154.6	70.125	0.922	64.7
526	41	150.6	68.311	0.926	63.3
527	27	167.8	76.112	0.913	69.5
531	73	230.2	104.416	0.866	90.4
532	54	187.5	85.048	0.897	76.3
538	25	132.2	59.965	0.940	56.4
540	32	140.3	63.639	0.933	59.4
541	20	137.6	62.414	0.936	58.4
547	12	95.5	43.318	0.969	42.0
548	20	147.5	66.905	0.928	62.1
550	21	148.5	67.358	0.927	62.4
552	18	140.0	63.503	0.934	59.3
554	18	130.0	58.967	0.941	55.5
555	21	147.0	66.678	0.928	61.9
556	19	148.0	67.131	0.927	62.2
557	23	132.6	60.146	0.939	56.5
558	13	112.6	51.074	0.951	48.6
549	18	117.0	53.070	0.951	50.5
551	21	149.5	67.812	0.927	62.9
559	19	117.4	53.251	0.950	50.6

Table 78.—Amount and Composition of Gain from Start to Slaughter.

Group	Age months	Animal	Condition	Empty Weight	Percent Water	Weight Water	Percent Fat	Weight Fat	Percent Nitrogen	Weight Nitrogen	Percent Ash	Weight Ash	Percent Phos-phorus	Weight Phos-phorus
			At slaughter	98,133	66.028	64,795	9.488	9,310.6	3.168	3,108.8	4.763	4,673.7	0.848	832.33
I	3	556	At start	62,200	70.100	43,602	5.200	3,234.4	3.180	1,978.0	4.750	2,954.5	0.839	521.86
			Gain	35,933	58.980	21,193	16.910	6,076.2	3.150	1,130.8	4.780	1,719.2	0.864	310.47
			At slaughter	78,071	67.562	52,746	7.234	5,647.5	3.175	2,478.4	4.894	3,820.9	0.853	665.91
II	3	554	At start	55,500	71.100	39,461	4.800	2,664.0	3.140	1,742.7	4.710	2,614.1	0.834	462.87
			Gain	22,571	58.860	13,285	13.220	2,983.5	3.260	735.7	5.350	1,206.8	0.900	203.04
			At slaughter	71,078	71.517	50,833	4.315	3,067.3	3.201	2,274.9	4.295	3,052.6	0.729	517.87
III	3	555	At start	61,900	70.200	43,454	5.100	3,156.9	3.180	1,968.4	4.750	2,940.3	0.838	518.72
			Gain	9,178	80.400	7,379	−0.980	−89.6	2.340	306.5	1.220	112.3	−0.009	−0.85
			At slaughter	172,797	57.213	98,862	20.773	35,895.9	2.725	4,708.5	3.998	6,908.3	0.723	1,250.16
I	5½	557	At start	56,500	71.000	40,115	4.800	2,712.0	3.150	1,779.8	4.710	2,661.2	0.835	471.78
			Gain	116,297	50.510	58,747	28.530	33,183.9	2.520	2,928.7	3.650	4,247.1	0.669	778.38
			At slaughter	99,349	64.388	63,969	10.356	10,288.8	3.093	3,073.2	4.937	4,905.1	0.870	864.21
II	5½	552	At start	59,300	70.600	41,866	5.000	2,965.0	3.170	1,879.8	4.740	2,810.8	0.837	496.34
			Gain	40,049	55.190	22,103	18.290	7,323.8	2.980	1,193.4	5.230	2,094.3	0.919	367.87
			At slaughter	85,988	67.800	58,300	6.689	5,751.6	3.221	2,770.1	4.807	4,133.4	0.857	737.10
III	5½	548	At start	62,100	70.100	43,532	5.200	3,229.2	3.180	1,974.8	4.750	2,949.8	0.839	521.02
			Gain	23,888	61.820	14,768	10.560	2,522.4	3.330	795.3	4.950	1,183.6	0.905	216.08
			A. slaughter	171,488	61.233	104,983	15.637	26,810.7	2.935	5,031.8	3.908	6,700.4	0.700	1,199.78
I	8½	547	At start	42,000	72.400	30,408	4.000	1,680.0	2.980	1,251.6	4.550	1,911.0	0.824	346.08
			Gain	129,448	57.610	74,575	19.410	25,130.7	2.920	3,780.2	3.700	4,789.4	0.659	853.70
			At slaughter	121,112	63.055	76,367	13.695	16,585.7	2.922	3,539.2	4.312	5,222.8	0.784	949.39
II	8½	550	At start	62,400	70.100	43,742	5.200	3,244.8	3.180	1,984.3	4.760	2,970.2	0.839	523.54
			Gain	58,712	55.570	32,625	22.720	13,340.9	2.650	1,554.9	3.840	2,252.6	0.725	425.85
			At slaughter	89,999	66.509	59,857	8.437	7,593.1	3.079	2,771.2	4.921	4,428.8	0.897	807.60
III	8½	558	At start	48,600	71.900	34,943	4.400	2,138.4	3.080	1,496.9	4.650	2,259.9	0.828	402.41
			Gain	41,399	60.180	24,914	13.180	5,454.7	3.080	1,274.3	5.240	2.168.9	0.979	405.19
			At slaughter	288,297	57.556	165,933	20.437	58,918.3	2.817	8,120.8	3.744	10,794.1	0.610	1,759.79
I	11	541	At start	58,400	70.700	41,289	4.900	2,861.6	3.160	1,845.4	4.730	2,762.3	0.836	488.22
			Gain	229,897	54.220	124,644	24.330	56,056.7	2.730	6,275.4	3.490	8,031.8	0.553	1,271.57
			At slaughter	274,357	54.424	149,316	24.421	66,999.9	3.714	7,445.3	3.946	10,824.9	0.730	2,002.23
I	11	505	At start	54,400	71.200	38,733	4.700	2,556.8	3.130	1,702.7	4.700	2,556.8	0.833	453.15
			Gain	219,957	50.270	110,583	29.300	64,443.1	2.610	5,742.6	3.760	8,268.1	0.704	1,549.08
			At slaughter	158,911	63.006	100 124	13.245	21,048.5	2.967	4,714.7	4.616	7,334.7	0.711	1,225.46
II	11	538	At start	56,400	71.000	40,044	4.800	2,707.2	3.150	1,776.6	4.710	2,656.4	0.835	470.94
			Gain	102,511	58.610	60,080	17.890	18,341.3	2.870	2,938.1	4.560	4,678.3	0.736	754.52
			At slaughter	236,429	60.371	142,735	16.031	37,903.0	2.923	6,910.6	4.869	11,512.8	0.895	2,116.15
II	11	503	At start	66,200	69.700	46,144	5.300	3,508.6	3.200	2,118.4	4.770	3,157.7	0.842	557.40
			Gain	170,229	56.740	96,591	20.200	34,394.4	2.820	4,792.2	4.910	8,355.1	0.915	1,558.75
			At slaugnter	137,726	64.800	89,247	11.512	15,855.4	2.913	4,011.3	4.523	6,229.2	0.803	1,105.98
III	11	540	At start	59,400	70.600	41,936	5.000	2,970.0	3.170	1,883.0	4.740	2,815.6	0.837	497.18
			Gain	78,326	60.400	47,311	16.450	12,885.4	2.720	2,128.3	4.360	3,413.6	0.777	608.80
			At slaughter	459,025	53.038	243,459	25.997	119,332.5	2.672	12,264.6	3.702	16,994.9	0.661	3,035.37
I	18	532	At start	76,300	68.300	52,113	6.000	4,578.0	3.200	2,441.6	4.810	3,670.0	0.850	648.55
			Gain	382,725	50.000	191,346	29.980	114,754.5	2.570	9,823.0	3.480	13,324.49	0.624	2,386.82

Table 78.—Amount and Composition of Gain from Start to Slaughter—Continued.

Group	Age months	Animal	Condition	Empty Weight	Percent Water	Weight Water	Percent Fat	Weight Fat	Percent Nitrogen	Weight Nitrogen	Percent Ash	Weight Ash	Percent Phos-phorus	Weight Phos-phorus
			At slaughter	192,005	65.411	125,592	9.951	19,105.6	3.017	5,792.2	4.969	9,540.5	0.879	1,688.27
III	18½	531	At start	90.400	66.400	60,026	8.200	7,412.8	3.200	2,892.8	4.850	4.384.4	0.860	777.44
			Gain	101,605	64.530	65,566	11.510	11,692.8	2.850	2,899.4	5.070	5,156.1	0.896	910.83
			At slaughter	475,854	50.933	242,366	28.735	136,735.0	2.577	12,264.1	3.921	18,658.4	0.708	3,366.90
I	21	504	At start	62,100	70.100	43,532	5.200	3,229.2	3.180	1,974.8	4.750	2,949.8	0.839	521.02
			Gain	413,754	48.060	198,834	32.270	133,505.8	2.490	10,289.3	3.800	15,708.6	0.688	2,845.88
			At slaughter	337,803	61.960	209,304	14.398	48,636.5	2.971	10,034.9	5.077	17,150.6	0.861	2,909.44
II	26	523	At start	56,400	71.000	40,044	4.800	2,707.2	3.150	1,776.6	4.710	2,656.4	0.835	470.94
			Gain	281,403	60.150	169,260	16.320	45,929.3	2.930	8,258.3	5.150	14,494.2	0.867	2,438.50
			At slaughter	265,587	64.115	170,280	11.344	30,126.9	3.087	8,199.5	4.861	12,911.0	0.801	2,126.98
III	26	525	At start	64,700	69.900	45,225	5.300	3,429.1	3.190	2,063.9	4.760	3,079.7	0.841	544.13
			Gain	200,887	62.250	125,055	13.290	26,697.8	3.050	6,135.6	4.890	9,831.3	0.788	1,582.85
			At slaughter	671,917	46.601	313,119	35.566	238,975.5	2.167	14,563.2	3.672	24,673.2	0.582	3,913.72
I	34	515	At start	49,100	71.800	35.254	4.400	2,160.4	3.080	1,512.3	4.660	2,288.1	0.828	406.55
			Gain	622,817	44.610	277,865	38.020	236,815.1	2.100	13,050.9	3.590	22,385.1	0.563	3,507.17
			At slaughter	418,896	58.014	243,018	18.759	78,579.9	2.899	12,142.4	4.850	20,316.2	0.758	3,174.44
II	34	507	At start	41,000	72.800	29,848	4.000	1.640.0	2.970	1,217.7	4.530	1,857.3	0.822	337.02
			Gain	377,896	56.410	213,170	20.360	76,939.9	2.890	10,924.7	4.880	18,458.9	0.751	2.837.42
			At slaughter	786,005	39.827	313,045	44.558	350,228.8	1.980	15,561.1	2.967	23,320.7	0.497	3,909.04
I	39½	527	At start	69,200	69.300	47,956	5.500	3,806.0	3.200	2,214.4	4.780	3,307.8	0.844	584.05
			Gain	716,805	36.980	265,089	48.330	346,422.8	1.860	13,346.7	2.790	20,012.9	0.464	3,324.99
			At slaughter	427,995	56.566	242,058	19.688	84,263.0	2.956	12,649.9	4.789	20,498.4	0.853	3,651.97
II	40	526	At start	63,300	70.000	44,310	5.200	3,291.6	3.190	2,019.3	4.760	3,013.1	0.840	531.72
			Gain	364,695	54.220	197,748	22.200	80,971.4	2.910	10,630.6	4.790	17,485.3	0.856	3,120.25
			At slaughter	322,234	63.491	204,591	10.202	32,874.7	3.258	10,498.9	5.630	18,141.7	0.979	3,156.16
III	40½	524	At start	61,300	70.300	43,094	5.100	3,126.3	3.180	1,949.3	4.750	2,911.8	0.838	513.69
			Gain	260,934	61.890	161,497	11.400	29,748.4	3.280	8,549.6	5.840	15,229.9	1.013	2,642.47
			At slaughter	771,142	41.396	319,219	41.792	322,276.3	2.051	15,819.3	3.122	24,073.7	0.585	4,507.90
I	44½	513	At start	46,300	72.100	33,382	4.200	1,944.6	3.050	1,412.2	4.160	2,134.4	0.826	382.44
			Gain	724,842	39.430	285,837	44.190	320,331.7	1.990	14,407.1	3.030	21,939.3	0.569	4,125.46
			At slaughter	444,424	57.625	256,101	16.571	73,645.3	3.203	14,236.6	4.966	22,068.9	0.866	3,847.63
II	44½	502	At start	47,800	72.000	34,416	4.350	2,079.3	3.070	1,467.5	4.640	2,217.9	0.827	395.31
			Gain	396,624	55.890	221,685	18.040	71,566.0	3.220	12,769.1	5.000	19,851.0	0.870	3,452.32
			At slaughter	391,461	58.369	228,490	16.015	62,609.6	3.184	12,464.4	4.928	19,290.4	0.873	3,418.30
III	45	509	At start	46,800	72.100	33,743	4.300	2,012.4	3.050	1,427.4	4.620	2,162.2	0.827	387.04
			Gain	344,661	56.500	194,747	17.580	60,597.2	3.200	11,037.0	4.970	17,128.2	0.879	3,031.26
			At slaughter	814,914	39.836	324,632	44.556	354,940.0	1.963	15,999.4	3.270	26,645.1	0.577	4,701.00
I	47	501	At start	43,000	72.300	31,089	4.100	1,763.0	3.000	1,290.0	4.570	1,965.1	0.824	354.32
			Gain	771,914	38.030	293,543	45.750	353,177.0	1.910	14,709.4	3.200	24,680.0	0.563	4,346.68
			At slaughter	493,877	52.666	260,103	23.697	117,034.5	2.879	14,217.6	5.014	24,764.9	0.891	4,399.23
II	48	512	At start	69,700	69.300	48,302	5.500	3,833.5	3.200	2,230.4	4.790	3,338.6	0.845	588.97
			Gain	424,177	49.930	211,801	26.690	113,201.0	2.830	11,987.2	5.050	21,426.3	0.898	3,810.26
			At slaughter	407,833	58.142	237,124	16.852	68,726.2	3.134	12,781.0	4.072	20,279.1	0.866	3,529.88
III	48	500	At start	50.900	71.600	36,444	4.500	2,290.5	3.100	1,577.9	4.680	2,382.1	0.830	422.47
			Gain	356,933	56.220	200,680	18.610	66,436.1	3.140	11,203.1	5.010	17,897.0	0.871	3,107.41

TABLE 79.—EMPTY WEIGHT AT AGE PREVIOUS ANIMAL WAS SLAUGHTERED.

Animal	Age Yrs.	Mos.	Days	Live weight at end feeding lbs.	Live weight at end feeding kgs.	Empty weight at slaughter kgs.	Per cent empty weight	Weight at age previous animal was slaughtered Live kgs.	Weight at age previous animal was slaughtered Empty kgs.
Group 1									
556	0	3	0	247.6	112.31	98.13	87.38	....	34.830
557	0	5	17	443.2	201.03	172.80	85.96	109.41	95.599
547	0	8	5	450.2	204.21	171.45	83.96	142.93	122.859
541	0	10	22	724.0	328.40	288.30	87.79	250.38	210.221
505	0	10	18	690.6	313.25	274.36	87.58	255.37	214.409
532	1	5	20	1133.0	513.92	459.03	89.32	324.00	284.439
504	1	8	26	1170.0	530.70	475.85	89.67	488.74	436.545
515	2	9	19	1632.2	740.35	671.92	90.76	539.05	483.363
527	3	3	15	1869.0	847.76	786.01	92.72	777.45	705.616
513	3	8	15	1898.4	861.10	771.14	89.55	782.17	725.229
501	3	11	0	1964.8	891.21	814.91	91.44	873.71	782.403
Group 2									
554	0	3	0	196.0	88.90	78.07	87.81	....	34.830
552	0	5	7	256.2	116.21	99.35	85.49	88.09	77.349
550	0	8	14	323.8	146.87	121.11	82.46	104.10	88.994
538	0	10	26	403.0	182.80	158.91	86.93	146.78	121.036
503	0	11	11	608.4	275.96	236.43	85.67	209.11	172.428
523	2	2	6	864.2	391.99	337.80	86.18	221.58	192.619
507	2	9	16	1014.4	460.12	418.90	91.04	440.12	379.294
526	3	4	0	1088.2	493.60	428.00	86.71	441.12	401.592
502	3	8	19	1138.6	516.46	444.42	86.05	491.69	426.346
512	3	11	21	1250.4	567.17	493.88	87.08	562.54	484.067
Group 3									
555	0	3	0	188.4	85.46	71.08	83.17	....	34.830
548	0	5	9	222.0	100.70	85.99	85.39	79.02	65.717
558	0	8	12	237.8	107.86	90.00	83.44	94.12	86.369
540	0	11	2	341.8	155.04	137.73	88.83	135.90	113.392
531	1	6	12	479.6	217.54	192.01	88.26	153.99	136.793
525	2	2	8	694.6	315.06	265.59	84.30	240.49	212.259
524	3	4	13	806.2	365.68	322.23	88.12	299.60	252.559
509	3	8	22	1004.2	455.50	391.46	85.94	416.26	366.808
500	3	11	26	1061.8	481.62	407.83	84.68	438.30	376.678

TABLE 80.—AMOUNT AND COMPOSITION OF GAIN BETWEEN EACH SUCCEEDING AGE.

Group I.

Age, months	Animal	Condition	Empty Weight	Per cent. Water	Weight Water	Per cent. Fat	Weight Fat	Per cent. Nitrogen	Weight Nitrogen	Per cent. Ash	Weight Ash	Per cent. Phosphorus	Weight Phosphorus
			Grams.		Grams.		Grams.		Grams.		Grams.		Grams.
0 — 3	556	At slaughter	98,133	66.028	64,795	9.488	9,310.6	3.168	3,108.8	4.763	4,673.7	0.848	832.33
		At birth	34.830	73.583	25,629	3.544	1,234.4	2.843	990.2	4.394	1,530.4	0.817	284.56
		Gain	63,303	61.870	39,166	12.760	8,076.2	3.350	2,118.6	4.970	3,143.3	0.865	547.77
3 — 5½	557	At slaughter	172,797	57.213	98,862	20.773	35,895.9	2.725	4,708.5	3.998	6,908.3	0.723	1,250.16
		At 3 mo	95,599	66.028	63,122	9.488	9,070.4	3.168	3,028.6	4.763	4,553.4	0.848	810.68
		Gain	77,198	46.300	35,740	34.750	26,825.5	2.180	1,679.9	3.050	2,354.9	0.569	439.48
5½— 8½	547	At slaughter	171,448	61.233	104,983	15.637	26,810.7	2.935	5,031.8	3.908	6,700.4	0.700	1,199.78
		At 5½ mo	122,859	57.213	70.291	20.773	25,521.5	2.725	3.247.9	3.998	4,911.9	0.723	888.27
		Gain	48,589	71.400	34,692	2.650	1,289.2	3.470	1,683.9	3.680	1,788.5	0.641	311.51
8½—11	541	At slaughter	288,297	57.556	165,933	20.437	58,918.3	2.817	8,120.8	3.744	10,794.1	0.610	1,759.79
		At 8½ mo	210,221	61.233	128,725	15.637	32.872.3	2.935	6,170.0	3.908	8,215.4	0.700	1,471.55
		Gain	78,076	47.660	37,208	33.360	26,046.0	2.500	1,950.8	3.300	2,578.7	0.369	288.24
8½—11	505	At slaughter	274,357	54.424	149,316	24.421	66,999.9	2.714	7,445.3	3.946	10,824.9	0.730	2,002.23
		At 8½ mo	214,409	61.233	131,289	15.637	33,527.1	2.935	6.292.9	3.908	8,379.1	0.700	1.500.86
		Gain	59,948	30.070	18,027	55.840	33,472.8	1.920	1,152.4	4.080	2,445.8	0.836	501.37
11 —18	532	At slaughter	459,025	53.038	243,459	25.997	119,332.5	2.672	12,264.6	3.702	16,994.9	0.661	3,035.37
		At 11 mo (541)	284,439	57.556	163,712	20.437	58,130.8	2.817	8,012.6	3.744	10,649.4	0.610	1,735.08
		Gain	174,586	45.680	79,747	35.060	61,201.7	2.440	4,252.0	3.630	6,345.5	0.745	1,300.29
18 —21	504	At slaughter	475,854	50.933	242,366	28.735	136,735.0	2.577	12,264.1	3.921	18,658.4	0.707	3,366.90
		At 18 mos	436,545	53.038	231,535	25.997	113,488.6	2.672	11,664.5	3.702	16,160.9	0.661	2,885.56
		Gain	39,309	27.550	10,831	59.140	23,246.4	1.530	559.6	6.350	2,497.5	1.225	481.34
21 —34	515	At slaughter	671,917	46.600	313,119	35.566	238,975.5	2.167	14,563.2	3.672	24,673.2	0.582	3,913.72
		At 21 mos	483,363	50.933	246,191	28.735	138,894.4	2.577	12,456.3	3.921	18,952.7	0.708	3,422.21
		Gain	188,554	35.500	66,928	53.080	100.081.1	1.120	2,106.9	3.030	5,720.5	0.261	491.51
34 —39½	527	At slaughter	786,005	39.827	313,045	44.558	350,228.8	1.980	15,561.1	2.967	23,320.7	0.497	3,909.04
		At 34 mos	705,616	46.601	328,824	35.566	250,959.4	2.167	15,920.7	3.672	25,910.2	0.582	4,106.69
		Gain	80,389	—19.630	—15,779	123.490	99,269.4	0.340	270.4	—3.220	—2,589.5	—0.246	—197.65
39½—44½	513	At slaughter	771,142	41.396	319,219	41.792	322,276.3	2.051	15,819.3	3.122	24,073.7	0.585	4,507.90
		At 39½ mos	725,229	39.827	288,837	44.558	323,147.5	1.980	14,359.5	2.967	21,517.5	0.497	3,604.39
		Gain	45,913	66.170	30,382	—1.900	—871.2	3.180	1,459.8	5.570	2,556.2	1.968	903.51
44½—47	501	At slaughter	814,914	39.836	324,632	43.556	354,940.0	1.963	15,999.4	3.270	26,645.1	0.577	4,701.00
		At 21 mos	782,403	41.396	323,884	41.792	326,981.9	2.051	16,047.1	3.122	24,426.6	0.585	4,577.06
		Gain	32,511	2.300	748	86.000	27,958.1	—0.150	—47.7	6.820	2,218.5	0.381	123.94
34 —39½	527	At slaughter	786,005	43.480	341,755	38.500	302.611.9	2.210	17,370.7	3.380	26,567.0	0.615	4,833.93
		At 34 mos	705,616	46.601	328,824	35.566	250,959.4	2.167	15,290.7	3.672	25,910.2	0.582	4,106.69
		Gain	80,389	16.090	12,931	64.250	51,652.5	2.590	2,080.0	0.820	656.8	0.905	727.24
39½—44½	513	At slaugnter	771,142	41.396	319,219	41.792	322.276,3	2.051	15,819.3	3.122	24,073.7	0.585	4,507.90
		At 39½ mo	725,229	43.480	315,330	38.500	279,213.2	2.210	16,027.6	3.380	24,512.7	0.615	4,460.16
		Gain	45,913	8.470	3,889	93.790	43,063.1	—0.450	—208.3	—0.960	—439.0	0.104	47.74

TABLE 80.—AMOUNT AND COMPOSITION OF GAIN BETWEEN EACH SUCCEEDING AGE—Continued.

Group II.

Age, months	Animal	Condition	Empty Weight	er cent. Water	Weight Water	Per cent. Fat	Weight Fat	Per cent. Nitrogen	Weight Nitrogen	Per cent. Ash	Weight Ash	Per cent. Phosphorus	Weight Pnosphorus
			Grams.		Grams.		Grams.		Grams.		Grams.		Grams.
0 — 3	554	At slaughter......	78,071	67.562	52,746	7.234	5,647.5	3.175	2,478.4	4.894	3,820.9	0.853	665.91
		At birth..........	34,830	73.583	25,629	3.544	1,234.4	2.843	990.2	4.394	1,530.4	0.817	284.56
		Gain.............	43,241	62.710	27,117	10.210	4,413.1	3.440	1,488.2	5.300	2,290.5	0.882	381.35
3 — 5½	552	At slaughter......	99,349	64.388	63,969	10.356	10,288.8	3.093	3,073.2	4.937	4,905.1	0.870	864.21
		At 3 mo..........	77,349	67.562	52,259	7.234	5,595.4	3.175	2,455.8	4.894	3,785.5	0.853	659.79
		Gain.............	22,000	53.230	11,710	21.330	4,693.4	2.810	617.4	5.090	1,119.6	0.929	204.42
5½— 8½	550	At slaughter......	121,112	63.055	76,367	13.695	16,585.7	2.922	3,539.2	4.312	5,222.8	0.784	949.39
		At 5½ mo........	88,994	64.388	57,301	10.356	9,216.2	3.093	2,752.6	4.397	4,393.6	0.870	774.25
		Gain.............	32,118	59.360	19,066	22.950	7,369.5	2.450	786.6	2.580	829.2	0.545	175.14
8½—11	538	At slaughter......	158,911	63.006	100,124	13.245	21,048.5	2.967	4,714.7	4.616	7,334.7	0.771	1,225.46
		At 8½ mo........	121,036	63.055	76,319	13.695	16,575.9	2.922	3,536.7	4.312	5,219.1	0.784	948.92
		Gain.............	37,875	62,850	23.805	11.810	4,472.6	3.110	1,178.0	5.590	2,115.6	0.730	276.54
8½—11	503	At slaughter......	236,429	60.371	142,735	16.031	37,903.0	2.923	6,910.6	4.869	11,512.8	0.895	2,116.15
		At 8½ mo........	172,428	63.055	108,724	13.695	23,614.0	2.922	5,038.3	4.312	7,435.1	0.784	1,351.84
		Gain.............	64,001	53.140	34,011	22.330	14,289.0	2.930	1,872.3	6.370	4,077.7	1.194	764.31
11 —26	523	At slaughter......	337,803	61.960	209,304	14.398	48,636.5	2.971	10,034.9	5.077	17,150.6	0.861	2,909.44
		At 11 mo. (538)...	192,619	63.006	121,362	13.245	25,512.4	2.967	5,715.0	4.616	8,891.3	0.771	1,485.09
		Gain.............	145,184	60.570	87,942	15.930	23,124.1	2.980	4,319.9	5.690	8,259.3	0.981	1,424.35
26 —34	507	At slaughter......	418,896	58.014	243,018	18.759	78,579.9	2.899	12,142.4	4.850	20,316.2	0.758	3,174.44
		At 26 mo.........	379,294	61.960	235,011	14.398	54,610.8	2.971	11,268.8	5.077	19,256.8	0.861	3,265.72
		Gain.............	39,602	20.220	8,007	60.520	23,969.1	2.210	873.6	2.680	1,059.4	—0.230	—91.28
34 —40	526	At slaughter......	427,995	56.556	242,058	19.688	84,263.0	2.956	12,649.9	4.789	20,498.4	0.853	3,651.97
		At 34 mo.........	401,592	58.014	232,930	18.759	75,334.6	2.899	11,642.2	4.850	19,477.2	0.758	3,044.07
		Gain.............	26,403	34.380	9,078	33.820	8,928.4	3.820	1,007.7	3.870	1,021.2	2.302	607.90
40 —44½	502	At slaughter......	444,424	57.625	256,101	16.571	73,645.3	3.203	14.236.6	4.966	22.068.9	0.866	3,847.63
		At 40 mo.........	426,346	56.556	241,124	19.688	83,939.0	2.956	12,602.8	4.789	20,417.7	0.853	3,636.73
		Gain.............	18,078	82.850	14,977	—56.940	—10,293.7	9.040	1,633.8	9.130	1,651.2	1.167	210.90
44½—48	512	At slaughter......	493,877	52.666	260,103	23.697	117,034.5	2.879	14,217.6	5.014	24,764.9	0.891	4,399.23
		At 44½ mo.......	484,067	57.625	278,944	16.571	80,214.7	3.203	15,504.7	4.966	24,038.8	0.866	4,192.02
		Gain.............	9,810	—192.100	—18,841	375.300	36,819.8	—13.120	—1,287.1	7.400	726.1	2.112	207.21
40 —44½	502	At slaughter......	444,424	56.030	249,011	20.300	90,218.1	2.870	12,755.0	4.460	19,821.3	0.797	3,542.06
		At 40 mos........	426,346	56.556	241,124	19.688	83,939.0	2.956	12,602.8	4.789	20,417.7	0.853	3,636.73
		Gain.............	18,078	43.630	7,887	34.730	6,279.1	0.840	152.2	—3.300	—596.4	—0.524	—91.67
44½—48	512	At slaughter......	493,877	52,666	260,103	23.697	117,034.5	2.879	14,217.6	5.014	24,764.9	0.891	4,399.23
		At 44½ mo.......	484,067	56.030	271,223	20.300	98,265.6	2.870	13,892.7	4.460	21,589.4	0.797	3,858.01
		Gain.............	9,810	—113.350	—11,120	191.320	18,768.9	3.310	324.9	32.370	3,175.5	5.517	541.22

Table 80.—Amount and Composition of Gain Between Each Succeeding Age—Continued.

Group III.

Age, months	Animal	Condition	Empty Weight	Per cent. Water	Weight Water	Per cent. Fat	Weight Fat	Per cent. Nitrogen	Weight Nitrogen	Per cent. Ash	Weight Ash	Per cent. Phosphorus	Weight Phosphorus
			Grams.		Grams.		Grams		Grams.		Grams.		Grams.
0 — 3	555	At slaughter......	71,078	71.517	50,833	4.315	3,067.3	3.201	2,274.9	4.295	3,052.6	0.729	517.87
		At birth..........	34,830	73.583	25,629	3.544	1,234.4	2.843	990.2	4.394	1,530.4	0.817	284.56
		Gain.............	36,248	69.530	25,204	5.060	1,832.9	3.540	1,284.7	4.200	1,522.2	0.644	233.31
3 — 5½	548	At slaughter......	85,988	67.800	58,300	6.689	5,751.6	3.221	2,770.1	4.807	4,133.4	0.857	737.10
		At 3 mo..........	65,717	71.517	46,999	4.315	2,835.7	3.201	2,103.6	4.295	2,822.5	0.729	479.08
		Gain.............	20,271	55.750	11,301	14.380	2,915.9	3.297	666.5	6.470	1,310.9	1.273	258.02
5½— 8½	558	At slaughter......	89,999	66.509	59,857	8.437	7,593.1	3.079	2,771.2	4.921	4,428.8	0.897	807.60
		At 5½ mo........	80,369	67.800	54,490	6.689	5,375.9	3.221	2,588.7	4.807	3,863.3	0.857	688.76
		Gain.............	9,630	55.730	5,367	23.020	2,217.2	1.900	182.5	5.870	565.5	1.234	118.84
8½—11	540	At slaughter......	137,726	64.800	89,247	11.512	15,855.4	2.913	4,011.3	4.523	6,229.2	0.803	1,105.98
		At 8½ mo........	113,392	66.509	75,416	8.437	9,566.9	3.079	3,491.3	4.921	5,580.0	0.897	1,017.13
		Gain.............	24,334	56.840	13,831	25.840	6,288.5	2.140	520.0	2.670	649.2	0.365	88.85
11 —18½	531	At slaughter......	192,005	65.411	125,592	9.951	19,105.6	3.017	5,792.2	4.969	9,540.5	0.879	1,688.27
		At 11 mo.........	136,793	64.800	88,642	11.512	15,747.6	2.913	3,984.8	4.523	6,187.1	0.803	1,098.45
		Gain.............	55,212	66.920	36,950	6.080	3,358.0	3.270	1,807.4	6.070	3,353.4	1.068	589.82
18½—26	525	At slaughter......	265,587	64.115	170,280	11.344	30,126.9	3.087	8,199.5	4.861	12,911.0	0.801	2,126.98
		At 18½ mo.......	212,259	65.411	138,841	9.951	21,121.9	3.017	6,403.9	4.969	10,547.1	0.879	1,865.76
		Gain.............	53,328	58.950	31,439	16.890	9,005.0	3.370	1,795.6	4.430	2,363.9	0.490	261.22
26 —40½	524	At slaughter......	322,234	63.491	204,591	10.202	32,874.7	3.258	10,498.9	5.630	18,141.7	0.979	3,156.16
		At 26 mo.........	252,559	64.115	161,928	11.344	28,650.3	3.087	7,796.5	4.861	12,276.9	0.801	2,023.00
		Gain.............	69,675	61.230	42,663	6.060	4,224.4	3.880	2,702.4	8.420	5,864.8	1.626	1,133.16
40½—45	509	At slaughter......	391,461	58.369	228,490	16.015	62,690.6	3.184	12,464.4	4.928	19,290.4	0.873	3,418.30
		At 40½ mo.......	366,808	63.491	232,890	10.202	37,421.8	3.258	11,950.6	5.630	20,651.3	0.979	3,591.05
		Gain.............	24,653	—17.850	—4,400	102.500	25,268.8	2.080	513.8	—5.520	—1,360.9	—0.701	—172.75
45 —48	500	At slaughter......	407,833	58.142	237,124	16.852	68,726.6	3.134	12,781.0	4.972	20,279.1	0.866	3,529.88
		At 45 mo.........	376,678	58.369	219,863	16.015	60,325.0	3.184	11,993.4	4.928	18,562.7	0.873	3,288.40
		Gain.............	31,155	55.400	17,261	26.970	8,401.6	2.530	787.6	5.510	1,716.4	0.775	241.48
26 —40½	524	At slaughter......	322,234	60.000	193,340	15.000	48,335.1	3.060	9,860.4	4.700	15,145.0	0.850	2,738.99
		At 26 mo.........	252,559	64.115	161,928	11.344	28,650.3	3.087	7,796.5	4.861	12,276.9	0.801	2,023.00
		Gain.............	69,675	45.080	31,412	28.250	19,684.8	2.960	2,063.9	4.120	2,868.1	1.028	715.99
40½—45	509	At slaughter......	391,461	58.369	228,490	16.015	62,690.6	3.184	12,464.4	4.928	19,290.4	0.873	3,418.30
		At 40½ mo.......	366,808	60.000	220,085	15.000	55,021.2	3.060	11,224.3	4.700	17,240.0	0.850	3,117.87
		Gain.............	24,653	34.090	8,405	31.110	7,669.4	5.030	1,240.1	8.320	2,050.0	1.219	300.43

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Observations on Winter Injury

I—Early and Late Winter Injury

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II—An Aftermath of Winter Injury

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Observations on Winter Injury
I.—Early and Late Winter Injury

F. C. Bradford

Destruction of flower buds without attendant damage to other parts of the tree is the most common manifestation of winter injury in the peach and apparently very uncommon in the apple. Conversely, injury to other tissues without attendant damage to flower buds seems relatively more common in the apple than in the peach. In short, blossom buds are ordinarily the susceptible point in the peach and the resistant part of the apple tree. The general recognition of the connection between responsiveness of peach flower buds to high temperatures in winter and the too frequent consequent damage from ordinary winter cold has fostered a rather widespread assumption that injury to flower buds of any kind must be attributed to this combination of weather conditions. For this reason an occurrence of injury confined to blossoms in the apple while peaches in the same orchards were wholly undamaged, constituting a case of injury supposedly due to premature starting from dormacy in a fruit supposedly least subject to this weakness, merits investigation and record.

MANIFESTATIONS

Late in December, 1921, it was noted that a small percentage of fruit buds on Jonathan trees in the University orchard at Columbia had been injured, the floral parts being clearly discolored. In the spring of 1922 these trees blossomed very heavily. Shortly after the blossoms had fallen, the unusual persistence of the bud scales and the peculiar behavior of the axillary buds attracted attention. In many cases the terminal buds were dead and growth was proceeding from axillary buds. Most of the dead buds abscissed, leaving a smooth, flat surface, as shown in Fig. 1. In other cases the terminal growth was very feeble and fruit had set from axial blossom clusters. An instance of this is shown in Fig. 2. Since in Jonathan the formation of axillary flower buds without accompanying flower buds on terminals has not been observed, the association of axillary blossoms with leafy terminals invited attention. Furthermore, the setting of fruit from axillary buds in such numbers as appeared this spring was unusual; ordinarily the terminal buds set fruit and the axillary buds do not.

Many spurs which had not blossomed this year bore fewer leaves than is usual in non-blossoming spurs. Figs. 3 and 4 show views from two angles of a spur of this type found on a Ben Davis tree. Careful examination of either reveals a sharply marked ring just above the lowest leaves. An enlarged view of a similar spur (Fig. 5) shows the significance of this appearance perhaps more clearly. Here the ring, just below the leaf insertions, is plainly visible. This ring, a single continuous line, is quite different from the composite belt of scale scars marking the transition from one year's growth to the next. It occurs only on fruiting wood at the point where the vegetative axis leaves the purse.

At the right of the spur, just below the ring, is a black protuberance; this is the dried remnant of a flower cluster which was killed in the bud. The purse, or cluster base, the swelling which bears the blossoms and fruit, so prominent in the majority of bearing spurs (cf. Fig. 15), is here reduced to extremely small dimensions. The vegetative axis, relatively small in many blossoming or bearing spurs, in these cases constitute nearly all the current season's growth. In some the purse is reduced to even smaller size and can scarcely be distinguished (Fig. 8). In others it is fairly conspicuous.

Fig. 6 is a photomicrograph of a longitudinal section of the bud shown in Fig. 5. Though this section does not pass through the exact center, the dead blossoms within the cluster are discernible. The smallness of the pith cylinder extending to the blossoms is rather better evidence than the possibly shrivelled blossoms could be, of the size of the bud at the time of the killing. Fig. 7, representing a January stage in an uninjured bud of another variety, is used here to illustrate the extent of the injury to the Jonathan bud. That part of the bud represented by the portion above the line **k k'** was killed. Growth continued from the vegetative point just below this (v), resulting in the growth shown to the left of and above the injured portion.

A section of another bud is shown in Fig. 9. In this case the dead tissue had abscissed and the pith cylinder extending to the point of abscission (**a**) is the best evidence of the former presence of blossoms at this point. Injury to the pith is shown at **k** and the growth from the vegetative point was less vigorous. More severe injury is shown in Fig. 10, also some regenerative tissue. Complete killing is shown in Fig. 11 and, in Fig. 12, complete killing followed by abscission.

Dissection of these twigs and spurs showed, in many cases, though not invariably, some discoloration of the pith. Generally when the bud had sloughed off, as shown in Fig. 1, little injury was visible in

Plate I.—Fig. 1. Jonathan, showing abscission of winter-killed terminal. Fig. 2. Jonathan, showing setting of fruit from axial blossom clusters. Figs. 3 and 4. Ben Davis spur, showing winter killing of blossoms. Fig. 5 Jonathan spur, showing dead blossoms. Fig. 6 Photomicrograph of section of spur shown in Fig. 5.

PLATE II.—Fig. 7. Uninjured bud. In injured buds, tissues above *k*-*k'* killed and growth proceeds from *v*. Fig. 8. Jonathan spur, showing dead blossoms at *k* and extreme reduction of purse. Fig. 9 Jonathan spur, showing abscission of dead blossoms at *a* and injury to pith at *k*. Fig 10. Similar injury involving greater area. Fig. 11. Whole bud killed. Fig. 12, bud killed and abscissed.

Plate III.—Fig. 13. Kieffer pear, showing replacement of killed spurs from supernumerary buds. Fig. 14. Kieffer pear spur, injured in spring of 1921, bearing in 1922. Injury shown in blackened wood. Fig. 15. Ben Davis spur, July, 1921. Bearing from normal and from second bloom.

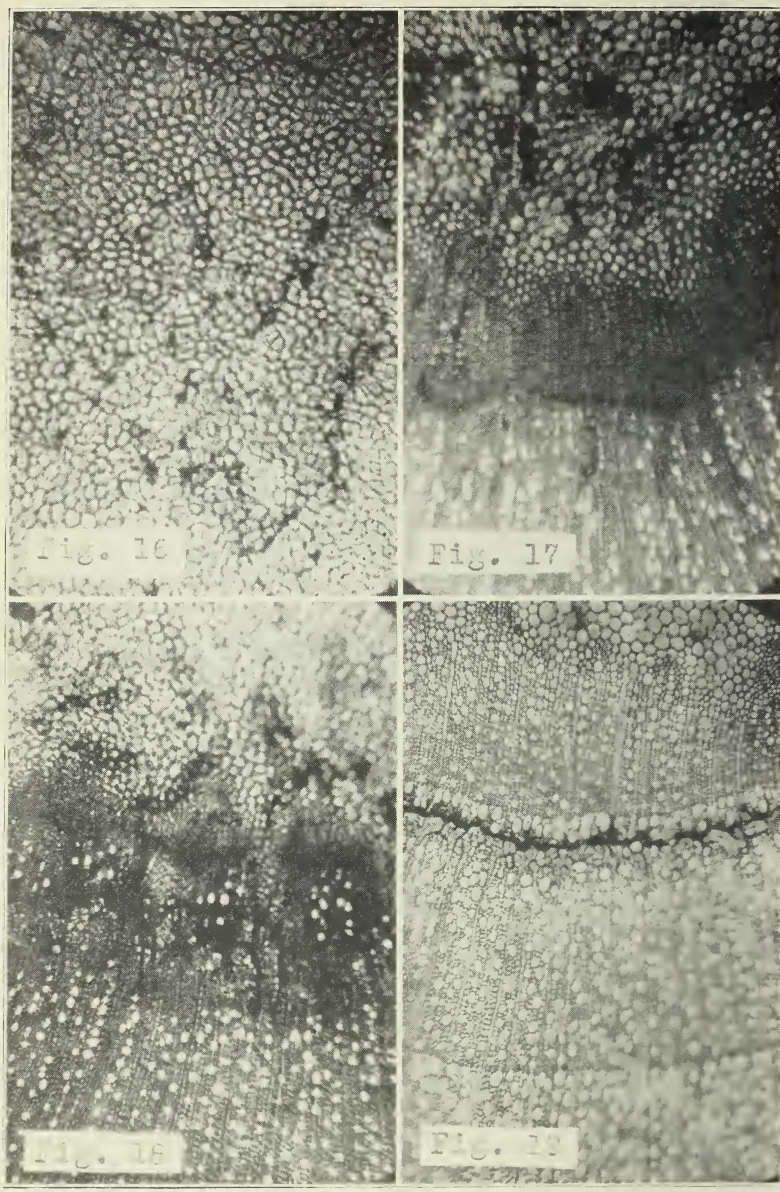

PLATE IV.—Series of sections of Kieffer pear. Fig. 16. Pith injury near tip of 1921 wood. Fig. 17. Injury to pith and wood in 1920 wood. Fig. 18. Section from lower level in 1920 wood; more wood and less pith injury. Fig. 19. Still lower on 1920 wood; injury confined to wood.

the remaining tissue. Some of the spurs in which the blossoms had been killed showed no further injury. In the majority of these cases, however, there were rather poorly defined small areas in which the pith was in some cases brown, in some cases orange. Other spurs, however, which were bearing normally showed somewhat the same injury. This has been observed in Oregon and in Missouri in other seasons.

Parenthetically it may be recorded that spurs somewhat similar in external appearance at this time to those just described, but with the purse better developed, were shown by dissection to be infected with fire blight. Here the discoloration was black and primarily in the vessels rather than the pith. Its course from the blossom attachments was easily traced. Leaves on infected spurs at this stage are still green and practically the only external evidence of infection is the rather flaccid condition of the purse.

OCCURRENCE

The distribution of this winter injury was rather general among the Jonathan trees in two parts of the University orchard. Other varieties examined, as Ben Davis, Ingram and Wealthy, showed it, but very rarely. Others, as Oldenburg, York and Gano, apparently had none. It was very common in *Malus prunifolia*. In Jonathan it affected certainly 10 per cent of the buds. It was found in young Jonathans in the cultivated orchard at Turner though less abundantly than in the sod orchard in Columbia. Possibly the trees in the better drained positions suffered less, but the differences were not marked. In a row on the northern boundary of the orchard injured buds were distinctly more plentiful on the north side of the trees. This might have been taken as evidence of a cold wind as a factor in the injury, were it not that elsewhere in the orchard injury was distinctly localized on other sides. Almost invariably it was most abundant on that side which faced an open space, regardless of orientation.

Much more consistent was the preponderance of injury in buds on terminal shoots over that on spurs. Though spurs greatly outnumber terminals, probably three-fourths of the cases of injury appeared on terminal shoots. The importance of this observation will appear later.

In the peach no sign of injury could be found, though many axillary leaf buds failed to open in the spring. Poorly developed axillary buds on vigorous shoots of many perennials, whether they are those

formed in the first flush of spring growth or those laid down just before growth stops in late autumn, are inclined to remain dormant. Consequently this failure to grow is no indication of winter injury, particularly in view of the absence of any evidence of injured tissue. In the peach the pith was brown in spots, but the cells were not collapsed. In this fruit the pith is short-lived and discoloration often occurs in new growth before midsummer. Fruit buds were, practically without exception, uninjured. Consequently it may be said that the peach came through the winter without injury.

TABLE 1.—PRECIPITATION AND TEMPERATURE AT COLUMBIA, SEPTEMBER TO DECEMBER, 1921, COMPARED TO THAT OF THE SAME MONTHS, 1911 TO 1920 INCLUSIVE.

Precipitation (inches)	Aug	Sept.	Oct.	Nov.	Dec.
1921	5.83	10.04	2.33	1.34	1.41
Average, 1911-1920	4.90	6.06	4.90	1.86	1.63
Maximum	7.83	9.69	7.68	3.24	2.94
Minimum	0.77	2.38	0.72	0.10	0.44
Daily Mean Temperature (°F.)					
1921		71.9	57.4	43.8	35.5
Average, 1911-1920		68.6	57.1	45.1	32.4
Maximum (monthly)		73.0	60.1	48.9	39.8
Minimum (monthly)		61.4	48.5	38.0	25.4
Absolute Minimum Temperature (°F.)					
1921		44	32	17	7
1911-1920		32	20	6	—9

CAUSE

The records of the United States Weather Bureau Station at Columbia, made available by Dr. George Reeder, section director for Missouri, are summarized in Table 1, to December 31, covering the period during which the injury occurred. They show the mean temperatures for September and December to have been rather well above the averages for the previous ten years and that for November somewhat lower, but in no case did they reach the extremes recorded in the previous ten years. The absolute minima for the several months have in each case been exceeded in other recent years. Unusual cold is evidently not the primary factor in this injury.

The precipitation record, however, shows an unusual rainfall in September, higher than any in the previous ten years; indeed it was exceeded but twice in 35 years. This rainfall, coupled with the considerable increase in mean temperature for the same month, undoubt-

edly tended to delay maturity. Raspberries made considerable new growth and fall blossoming of cherries was rather widespread. Some Japanese plums in the University orchard were partly in blossom in October. Though the subsequent winter was not at all remarkable for cold weather, in either duration or intensity, it resulted in practically complete destruction of red and purple raspberry canes and serious damage to black raspberries.

Injury confined to flower buds during early winter has been recorded but rarely. Maynard[4]* and Bartlett[1] described cases of December killing of peach buds in Massachusetts. In the case cited by Maynard the cold was not intense (10°F.), but it followed warm weather during which the blossoms were observed to develop. Chandler[3] found mild injury to peach blossom buds in New York during the winter of 1914-1915. The previous August had been characterized by heavy precipitation. The coldest temperature of the winter, —9°F., occurred in December. The injury was in the pith of the bud and of the twig and apparently had no effect beyond retarding blossoming. In these cases it is not altogether clear whether the buds had started to develop or had failed to mature.

The only careful report of winter injury to blossom buds in apple unaccompanied by further injury is that of a case observed by Whipple[5] in Montana. This form is apparently identical in its manifestations with that just described for Columbia. Though this form of injury seems rare, it is quite possible, as Whipple points out, that, since the injury escapes casual observation, it may occur from time to time and pass unnoticed. Whipple suggested that the damage in Montana might have been due to thawing in high winds or to freezing after warm weather in January or February.

All the evidence in the occurrence at Columbia, however, connects immaturity with the injury. It followed weather conditions inviting and in many cases leading directly to immaturity injuries in other fruits. Peaches, far more susceptible to injury from premature development, were entirely uninjured. The greater injury on open sides may have been due to prolonged growth as much as to greater exposure. In the varieties affected, damage was greatest in the terminals on shoots; these are late in differentiating flower buds, late in maturing and late in starting from dormancy. Some late blossoming varieties were affected while some early blossoming varieties escaped. Finally, the injury had occurred before the last of December.

*This and subsequent superscript numerals refer to literature cited in the Bibliography.

IMPLICATIONS

Attention of fruit growers in Missouri has been focused on premature starting of buds during winter rather than on immaturity. In this case peach trees in the same orchard showed no injury, either in wood or in fruit bud. In addition to weather, other conditions were particularly favorable to injury from immaturity in the peach this winter, for, following the Easter freeze in 1921 the trees had been cut back to wood 2 or 3 inches in diameter and had made growths of three to 6 or 7 feet, with secondary and even tertiary branches. Consequently their immunity from injury while Jonathan apples were afflicted indicates that in the peach at Columbia immaturity is less important than premature starting. On the other hand, so far as concerns the apple, evidence is accumulating in a chain, of which the case here recorded is but one link, that even to Central Missouri, as is the case farther north, immaturity is of no mean importance. Crown rot in Grimes and crotch injury in Stayman are presumably due to injury consequent upon immaturity. Cardinell has found serious cases of winter injury—with heart rot as the consequence—in young apples, evidently tracing to immaturity and cold in the fall of 1917. Injuries due to immaturity are not patent. The type described here might well escape observation and the crop failure be attributed to lack of fruit bud formation. Injuries to other tissues are often unnoted until brought to attenion by the wood-destroying fungi which find entrance through such lesions, or until the bark comes away, long after the weather conditions responsible for the injury have passed from recollection. In many cases such injuries are attributed to fungi and referred to under the general term "canker'.

If the conventional notions of the effects of cultivation be accepted, peaches and apples may be bad neighbors in Central Missouri orchards, for the cultural practices which, by inducing late growth, tend to make peaches resist stimulation from warm weather in January and February tend to make some apples more subject to injury in November and December. When peaches are used as fillers in apple orchards, cultural practices designed to protect either fruit against winter injury are likely to make the other more susceptible.

However, it should be recognized that the comparison made here is between peaches in cultivated soil and apples in sod. The generally accepted views of the effects of these two systems of management are, for the most part, founded on investigations in sections with a shorter and uniform growing season. For many crops there are in Missouri

two rather distinct growing seasons, separated by a season of dry, hot weather. In some cases, as with potatoes and cabbage, this may be due chiefly to the excessively high temperature of midsummer, but with others dry weather has its undoubted influence. The raspberry, companion of the potato and the cabbage in ability to grow where the summers are too cool to ripen grain, shows the same reaction to the growing season of Central Missouri. Immaturity injury in this fruit occurs every year in varying degree at Columbia before intense cold sets in; it may be produced by temperatures certainly no lower than 12°F. and possibly higher. In late August the canes are often more nearly mature than they are in October, following the moderate temperature and greater rainfall of September. Those which grow through August seem to mature better than those which stop growing at this time. Card[2] found in New York that under some circumstances the first shoots to start in the spring may be more tender in the following winter than those starting somewhat later. Prolonged tillage through the dry season may have the actual effect of inducing final maturity by so prolonging the first flush of growth that the second growth does not start. In short, for this fruit the growing season here is apparently too long; the canes mature and then resume growth.

On the other hand, the peach, adjusted to warmer summers, suffers little or no check from heat during its growing season. The long period of warm weather enables this tree to mature properly despite high cultivation. In fact, prolonged cultivation makes it more hardy.

The apple, with growing season temperature requirements higher than those of the raspberry and lower than those of the peach, undoubtedly suffers more or less here from immaturity. The evidence at hand, however, does not warrant any conjecture as to the effects of tillage on maturity in this fruit. The smaller amount of injury in the cultivated trees at Turner than in the sod orchard at Columbia, eight miles away, is interesting, possibly suggestive, but certainly not indicative. The greater prevalence of injury on terminals than on spurs at Columbia points in the opposite direction. Consequently at present it cannot be stated definitely whether this immaturity injury is due to prolonged growth or to renewed growth.

One thing becomes increasingly evident. Hardiness in Central Missouri is more complicated than it is farther north or farther south. In some regions it is largely a matter of maturity, in others a matter of continuing dormancy. Here it is in some fruits the first, in other fruits the second. This is the first complication. The second complication comes from the fact that immaturity alone, a rather simple mat-

ter farther north, is here possibly induced by the very practices that obviate it elsewhere. Finally, since this section shares northern and southern winter weather, extreme measures for guarding against one type of injury may be efficacious in one winter and injurious in the next. Solution of the problems raised will depend on recognition of the types of injury to which each fruit is subject, determination of the probability of the occurrence of weather conditions leading to each type and formulation for each fruit of cultural practices which, over a period of years, will reduce the injuries most likely to occur.

VARIABILITY OF HARDINESS

After the Easter freeze of 1921 the Kieffer pears showed more damage than any other trees in the University orchard. Many spurs were killed, many branches were killed back well into 1920 wood and older wood was discolored. Other pears, such as Garber, Tyson and Surprise, were injured but little. Since the freeze the recuperative ability of Kieffer has been as remarkable as was its susceptibility. The majority of the killed spurs have been replaced by new growths arising from supernumerary buds at the base of the old spurs (Fig. 13), and the spurs whose wood was blackened in 1921 are bearing in 1922 (Fig. 14).

Since this variety had proved so tender in the spring of 1921, it was examined for injury occurring in the late months of the same year. Evidence of injury to pith near the tip of 1921 wood was plentiful (Fig. 16), but there was no indication of injury to fruit buds and little or no indication of injury to wood. Farther back on these same branches showing pith injury in the 1921 wood, appeared injury of another kind. Just below the point where growth was resumed in 1921 both pith and wood were injured (Figs. 17 and 18). Still farther back, but yet in 1920 wood, the injury was confined to the wood. In gross appearance there was a ring of blackened tissue, which is shown by microscopic examination to be very narrow (Fig. 19). Inside the blackened ring is a narrow belt of new wood, one or two cells wide, composed of wood laid down in the spring of 1921 before the freeze. The injury was confined to parenchymatous tissue and the wood just laid down was hardy enough to withstand the freezing.

Discoloration of pith is not invariably a sign of winter injury, but, under the circumstances of its occurrence in the material discussed here, it may be taken as such. The injury to the pith in the 1921 wood was undoubtedly an immaturity injury. The injury to the pith in the 1920 wood may have been due to the weather of the 1920-1921 winter or

to the Easter freeze of 1921. In any case, it is clear that the most tender tissue in the fall of 1921 was the pith while in the spring of the same year it was the wood.

Extensive examination of 1920 wood in other pears and several varieties of apple showed no wood injury from the Easter freeze comparable to that in Kieffer. In some cases Ben Davis 1920 wood showed a dark ring (Fig. 3). On microscopic examination this was found to be, not injured tissue, but a false annual ring caused by the check to growth resulting apparently from the killing of the foliage in the same freeze.

The pear trees in the University orchard stand within a few feet of many Jonathan and Ben Davis trees and receive the same cultural treatment. These Jonathans show no wood injury from the Easter freeze, Ben Davis only a check to growth, while Kieffer was severely affected. In the fall of the same year, however, conditions were reversed; Jonathan was injured rather extensively, Ben Davis much less and Kieffer least of all. This condition, coupled with the reversal of the accepted comparative hardiness of the peach and the apple, illustrates anew the fact that hardiness is consitutional only in so far as conditions producing hardiness are constitutional. It is a condition rather than a quality. A given fruit is hardy in a locality as it reacts to the ordinary climatic conditions of that locality and comparative hardiness may be reversed in various localities according as the spring or the fall injuries are likely to prevail.

THE "SECOND BLOOM"

Following a frost causing widespread damage to blossoms and fruit crop there is frequently a flood of reports of crops borne on "second bloom" pushed out as a consequence of the injury to the first crop. The occurrence at times of second bloom in rather considerable quantity is unquestionable. After a destructive frost it is naturally more noticeable than it would be in a frostless season when it would come on about at the end of the first bloom. Its occurrence, however, is not necessarily a consequence of frost injury. It was noted in great abundance in the University orchard at Columbia in the spring of 1921 before any frost had occurred and in the spring of 1922 when there was no damage from frost. Fig. 15, showing a Ben Davis spur taken in the summer of 1920, is significant. Growth for that year started at g. One apple results from the first bloom and one from the second. Clearly in this case the destruction of the first bloom is not concerned with the formation of the second.

SUMMARY

1. Killing of many fruit buds in the apple occurred early in the winter of 1921-1922 in the University orchard at Columbia.

2. The attendant circumstances indicate that this injury was connected with immaturity.

3. Many plants with low optimum growing temperatures have, in Central Missouri, two distinct growing seasons separated by a hot, dry midsummer. The raspberry apparently belongs in this group.

4. Other plants, with higher optima, grow rather uniformily through the season. This group includes the peach.

5. Sod culture may have the effect of accentuating the duality of the growing season for the plants with low optima. Consequently its effect on maturity in these plants may be directly opposite that recognized in regions with short and relatively cool growing seasons.

6. Available evidence is not sufficient to indicate how tillage affects maturity in the apple in Central Missouri.

7. In the Kieffer pear the relative hardiness of the various tissues appears to vary with the season.

8. The Kieffer pear, under the conditions discussed in this paper, is more tender in the wood in the spring than the Jonathan apple, but more hardy in fruit buds in the fall.

9. The so-called second bloom is not necessarily the consequence of the destruction of the "first" or normal bloom.

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II.—An Aftermath of Winter Injury

H. A. Cardinell

In the course of some continuing demonstration work in 1920 and 1921 in a young orchard at Fortescue, Holt County, Missouri, attention was drawn to the failure of the pruning wounds to heal. Whereever any wood was removed, large or small, callus formation was very slow or failed altogether (Figure 6). Not only did wounds which should have healed in one season fail to cover over, but the wood in the immediate neighborhood seemed dead. Wounds disinfected and some both disinfected and painted healed no better than those untreated. Cuts made below old wounds revealed much dead wood in the center, surrounded by more or less live wood. Cuts through the trunk still lower on the tree, in many cases down to within three or four inches of the ground, showed the same condition (Fig. 4). For reasons which will appear later in this paper, it was possible to examine 1243 trees this spring. In this group only a few cases were found of discoloration extending below the graft union and fully 50 per cent of the trees were not injured below three or four inches above the ground as shown at **k** in Fig. 4.

Aside from this failure of wounds to heal properly the trees presented no unusual appearance, except in some extreme instances. By the spring of 1922 the trees most affected, though many of these same trees were making 20 to 40 inches of growth each year, as shown in Fig. 5, had one or two dead limbs to the tree. At the base of these limbs the wood on the trunks was practically all dead. In general, however, the trees were making very good growth and on casual observation the orchard would have appeared in excellent condition.

It is no uncommon occurrence to find black-hearted limbs or trunks on trees that have been growing and fruiting in a perfectly satisfactory manner. This condition is known to be caused by winter injury, sometimes from ordinary cold in conjunction with an immature condition of the tree. It occurs when the cold is severe enough to kill the wood but still not severe enough to kill the hardier cambium. Consequently in the following spring the cambium may resume growth and surround the dead area with a layer of new tissue. Sometimes these blackened regions are found surrounded by healthy wood showing 20 or more annual rings, indicating that the injury had occurred as many years previously and apparently had not interfered materially

with the tree's life or functions. In itself the condition is not serious, particularly in older trees. In the case here considered, however, there were two disturbing circumstances: (1) the failure of the wounds to heal, already mentioned, and (2) the fact that the discoloration was evidently advancing with the growth, spreading into new wood (Fig. 3, at B and C). This made diagnosis of the cause and prognosis of the ultimate effects somewhat uncertain.

HISTORY OF THE CASE

The trees involved stand in a 60-acre block, on level but well drained Missouri River bottom land. This orchard is one of the properties of George Hitz & Company of Indianapolis and is managed by Mr. C. E. Hitz. In the spring of 1918, yearling trees to the number of 2,997 were planted and in the fall of the same year 567 two-year-olds were set. Jonathans were planted as permanent trees, with fillers of five varieties: Ben Davis, Delicious, Stayman, Grimes and Ingram. All the stock used came from a nursery at St. Joseph, Missouri.

While these trees were being cut back subsequent to planting, Mr. Hitz noticed that there was a slight discoloration in the wood. During the summer of the same year a pathologist from the United States Department of Agriculture, visiting the orchard on another errand, examined these trees and diagnosed the trouble as winter injury.

DIAGNOSIS

The complication already alluded to and the resemblance of some of the wounds to cankers of fire blight, so common on Jonathan in Northwest Missouri, rather obscured the case. Specimens of injured wood were submitted to pathologists in various sections of the country and the possibility of several other disorders eliminated. In February, 1922, a shipment of injured trees was sent to M. B. Waite, Pathologist in Charge, Fruit Disease Investigations, U. S. Department of Agriculture.

Under date of February 25, Waite states: "I have given these samples careful study. The main trouble is winter injury. It is complicated by secondary trouble due to wood-rot fungi. These wood-rot fungi have produced a heart rot by entering the frozen injured centers of the trunks and main branches, and the wood-rot fungi have extended the injury somewhat, and perhaps complicated and confused the primary injury. * * * There are indications on these samples that they may have been frozen a second time. I have often noticed that

trees once injured by freezing appear slightly more susceptible. Part of the two-year wood and most of the one-year wood is sound."

Of the discoloration in the one-year-old wood Waite says: "This appears to be partly due to the growth of the wood-rot fungus from the diseased part up into the healthy tissue. One of the samples shows the tip of a small trunk which has been killed completely and shows the fungus fruiting.* Mr. W. H. Diehl of this bureau has identified this fungus as *Irpex tulipifera Schw*".

Weather records indicate several possibilities of winter injury in the time since these trees stood in the nursery, in the summer of 1917. However, inasmuch as injury to these trees is known to have occurred prior to planting in 1918 and the secondary injury is less certain, interest centers in the weather from October, 1917, to March, 1918. The mean temperature for the state as a whole was below normal during most of 1917 and particularly in October and December. The October mean temperature was the lowest on record. Killing frosts occurred on October 6, ten days earlier than the average. That fall will be remembered by many people in this section for the great amount of soft corn.

Table 1.—Precipitation at St. Joseph, Missouri.
(In Inches)

	Aug.	Sept.	Oct.	Nov.	Dec.
1917	5.80	1.60	0.80	0.04	0.16
Average, 1888-1917	4.37	3.34	2.62	1.71	0.96

The Weather Bureau records for St. Joseph, where the trees discussed in this paper were grown, indicate that the preceding autumn was rather dryer than the average. August, however, had a rainfall 1.4 inches above the average. Whether this could have had any material effect in prolonging growth and deferring maturity is problematical.

Table 2.—Minimum Temperatures at St. Joseph, Missouri.
(In degrees F.)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1917-18	20	17	—13	—19	—13	17
1909-1917	22	5	—10	—24	—16	—4

*After the manuscript was prepared many ungrafted trees had died and one type of fruiting body was noticed on all. This was identified Sept. 8, 1922, by Diehl as *Polystictus versicolor*, Fr.

Minimum temperatures lower than any since 1909, when the St. Joseph record begins, occurred in October and December. Just when the injury to these trees occurred, cannot be stated definitey. Selby records extensive damage in Ohio, involving even complete killing in some cases, by a temperature of 18° in October. Twenty degrees in October would seem more dangerous, particularly to nursery stock, than —13° in December, the other month of record-making temperature.

The date of digging these trees is not known. If they were, according to the prevailing practice, dug in the fall, the period of injury is fixed without question. Without this evidence, however, the probability of the October minimum being the chief factor in the damage is strong.

TABLE 3.—MINIMUM TEMPERATURES AT GENEVA, N. Y.
(In degrees F.)

	Oct.	Nov.	Dec.	Jan.	Feb.
1917-18	26.0	9.0	—18.0	—10.0	—11.0
1909-17	26.0	16.0	— 6.0	—12.0	—14.0
1883-1909	20.5	8.0	—15.5	—18.7	—21.0

Table 3, compiled from reports of the New York Agricultural Experiment Station at Geneva, which is a considerable nursery center and located in a section where immaturity is generally known to be the chief factor in hardiness, is used here for comparison. The October, 1917, minimum for St. Joseph is lower than at Geneva for the same year; it is in fact a trifle lower than any in the long series of records for this place.

Whether or not this particular injury was received in October, if immaturity is likely to be a factor in winter injury at Geneva, N. Y., it is likely to be a factor at St. Joseph, Mo. Table 4, giving in detail the data summarized in Tables 2 and 3, shows this clearly. In the nine years for which data are available, the October minimum for St. Joseph has been lower than that for Geneva in five, identical in three and higher in one. The November minimum has been lower in five years, higher in three and identical in one. If absolute cold at any time be considered the chief cause of injury, the Geneva absolute minimum of —18°F. is offset by one of —24°F. for St. Joseph.

It is true that the higher maximum and mean temperatures of the fall months at St. Joseph may under certain conditions have some influence in hastening maturity. It is also true, however, that they may

PLATE V.—Fig. 1 (Left) Jonathan, 4 years after planting in the orchard, showing growth condition and lack of external evidence that would indicate the condition shown in Fig. 7, a cross section of the same trunk. Fig. 2. (Right) Jonathan, four years after planting. Compare this view with the cross sections of the same tree shown in Fig. 3. Photographed Mar. 28, 1922.

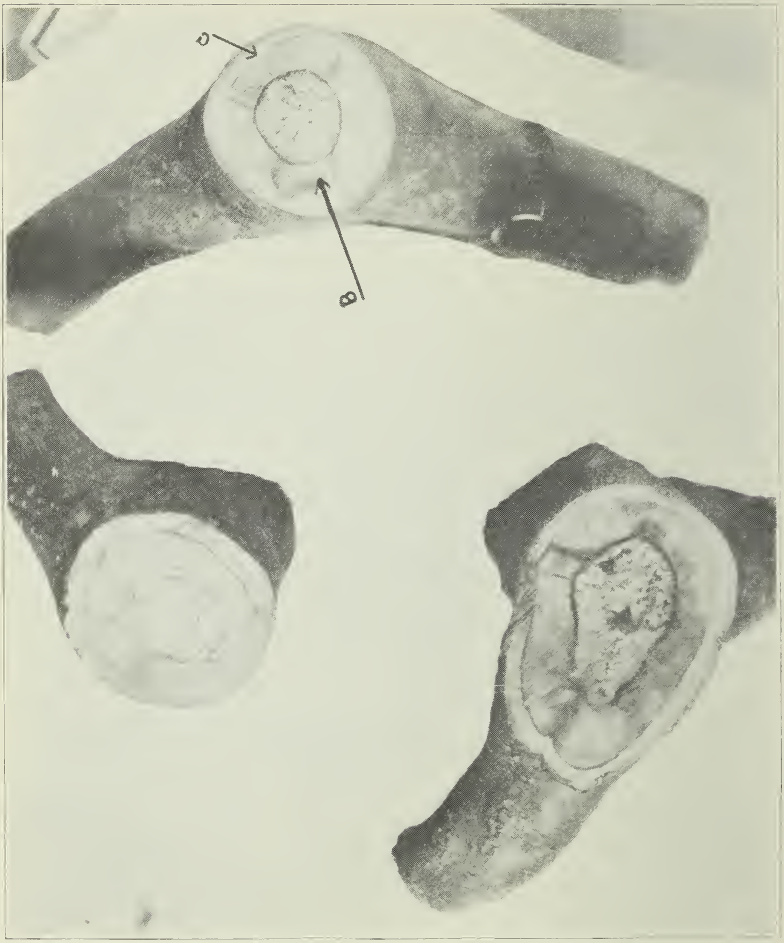

PLATE VI.—Fig 3. Jonathan, four years from time of planting, showing injured areas and heart rot rapidly advancing in later annual rings of apparently sound wood.

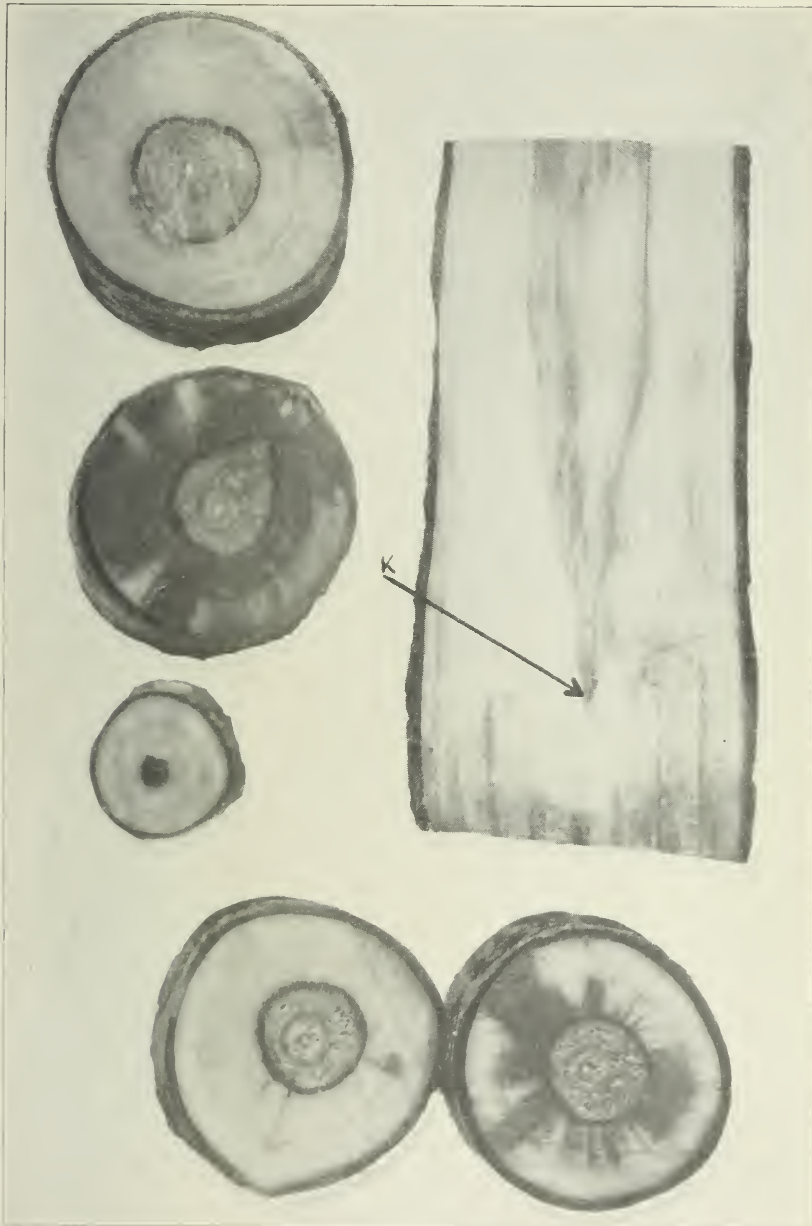

Plate VII.—Fig. 4. Jonathan, four years after planting showing longitudinal and cross section views of one tree through trunk and scaffold limbs. In a large percentage of the trees cut off, the injury terminated in a point a few inches above the ground.

PLATE VIII.—Fig 5. Ingram, four years old, showing remarkable growth in spite of the gradual loss of limbs which died each year as an indirect result of the injury. Fig. 6. Jonathan, a small limb removed during early training of the tree. All such wounds had been treated with disinfectant paint at the time of pruning. Wounds started to heal and the entrance of heart rot stopped all callus formation at that point. Fig. 7 Jonathan, cross section through the trunk of a four-year-old tree, showing action of heart rot. Fig. 8. Jonathan graft, showing one of the 1243 trees grafted during the week of March 26, 1922. Photographed August 14, 1922.

have some influence in the opposite direction. The average rainfall at St. Joseph in August, September and October is greater than that at Geneva; for these three months the figures are, respectively: at St. Joseph, 4.37, 3.34 and 2.62 inches; at Geneva, 3.30, 2.42 and 2.50 inches. When high rainfall is combined with high temperature, growth is prolonged and the first low temperatures are more likely to be damaging.

TABLE 4.—MINIMUM TEMPERATURES AT ST. JOSEPH, MO., AND AT GENEVA, N. Y., 1909-1918 INCLUSIVE.

Year	October		November		December		January		February	
	St. Joseph	Geneva	St. Joseph	Geneva	St. Joseph	Geneva	St. Joseph	Geneva	St. Joseph	Geneva
1909-10	27	27	19	21	—10	1	—13	—8	—5	—3
1910-11	28	26	20	21	8	—2.5	—11	—1	9	4
1911-12	32	33	5	18	— 4	13	—24	—12	—6	—10
1912-13	31	31	20	20	8	12	— 4	8	—2	—10
1913-14	22	29	26	22	11	6	8	—9	—7	—14
1914-15	25	26	7	16	— 8	—6	—12	—3	13	—10
1915-16	29	29	23	21	4	4	—19	—3	—4	—8
1916-17	24	29	12	16	9	4	— 8	1	—16	—8
1917-18	20	26	17	9	—13	—18	—19	10	—13	—11

IMPORTANCE

In a large number of cases occurring in this section winter injury of apples does not command attention at the time of its occurrence. It may induce minor injuries, the consequences of which are not revealed until the original cause is obscured. When a crop of peach buds is killed the loss is plain, but when a small area of bark is killed it receives little attention until decay ensues and by this time possible winter injury is forgotten. This very subtlety of winter injury makes difficult any appraisal of its extent. In the case discussed here the injury was slight. It was noticed at the time of setting the trees, but was thought of no importance. It did not affect the growth of the trees and would have been forgotten but for the work of the wood-destroying fungi. Many cases undoubtedly occur without untoward consequence; in many others the trees will grow for some years and when they begin to go to pieces the evidence to connect the condition with a slight winter injury several years back will be scant indeed.

TREATMENT

Detailed account of the treatment given this orchard following diagnosis of the condition will be published elsewhere. Briefly sum-

marized, it consisted in cutting back to sound wood, frequently to within a few inches of the ground and grafting the stubs (Fig. 8). A few trees cut back without grafting, after growth had started and when the carbohydrate reserve was low, died. Those treated earlier, with grafts inserted in the crowns, have made a practically perfect stand and are growing vigorously. This procedure has involved the sacrifice of the wood grown in the four years these trees have stood in the orchard; but, with proper attention to the grafts, it will ensure perfectly sound trees, with every promise of long life and productiveness.

CONCLUSIONS

Though winter conditions rarely kill apple trees outright in this section, they may have hardly less serious consequences. Evidence of winter injury should, therefore, put the grower on his guard. If new evidence appears every few years it may signify the need of revision of his cultural practices. Injury to wood at any time justifies great care in pruning. If the cuts can be made far enough back to remove all injured wood, there is little danger of infection. If the removal of all injured wood is not practicable there are two courses remaining: (1) careful disinfection and painting of all wounds, (2) omission of pruning altogether till the cuts can be made in sound tissue growing subsequent to the freeze. The practicability of these methods will be discussed elsewhere. However, one guiding principle may be stated: injured wood should not be exposed. Sealed within living wood, it is harmless; exposed it is a source of constant danger.

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Observations on Winter Injury

I—Early and Late Winter Injury

II—An Aftermath of Winter Injury

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